TSUNAMI

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NEWSLETTER

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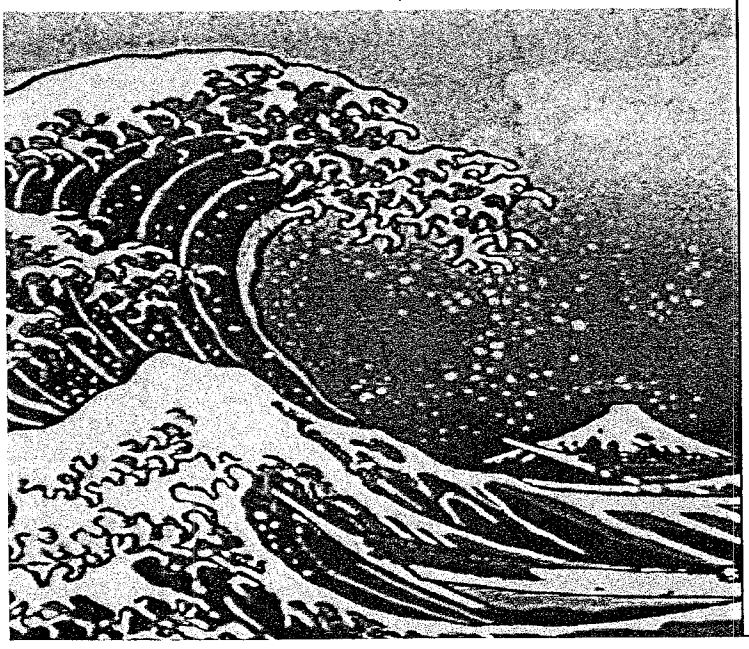
TSUNAMI NEWSLETTER is published annually by the International Tsunami Information Center (ITIC) to bring news and information to scientists, engineers, educators, community protection agencies, and governments throughout the world.

We welcome contributions from our readers.

The ITIC is maintained by the U.S. National Oceanic & Atmospheric Administration (NOAA) for the Intergovernmental Oceanographic Commission (IOC). The Center's mission is to mitigate the effects of tsunamis throughout the Pacific.



MEMBER STATES

Present membership of the IOC International Coordination Group for the Tsunami Warning System in the Pacific (ICG/ITSU) comprises the following 25 States:

AUSTRALIA
CANADA
CHILE
CHINA
COLOMBIA
COMMONWEALTH OF INDEPENDENT STATES, RUSSIAN FEDERATION
COOK ISLANDS
COSTA RICA
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA
ECUADOR
FIJI
FRANCE
GUATEMALA
INDONESIA
JAPAN
MEXICO
NEW ZEALAND
NICARAGUA
PERU
PHILIPPINES
REPUBLIC OF KOREA
SINGAPORE
THAILAND
UNITED STATES OF AMERICA
WESTERN SAMOA

INTRODUCTION

Greetings from the Director:

Finally after a hiatus of a year and a half another issue of "Tsunami Newsletter" is appearing. Because of the gap the ITIC has received numerous requests from institutional libraries and individuals that can best be summarized by the question, "What's happened?" The answer is that the Director decided to take a long look at the methods the ITIC uses to disseminate information to its public. During this period there have been changes in the ITIC personnel that contributed to the dry spell between Newsletter publications. The Director now feels he has clear vision of how he would like to proceed with a restructuring the ITIC's information products. Although final approval of the proposed changes must be made by the Member States present at the next ICG/ITSU meeting scheduled for Seoul, Korea in October 1999, the following is a brief outline of the information dissemination structure the Director envisions.

The first source of information available to the tsunami community is the Tsunami Bulletin Board (TBB). The TBB was originally developed by the Pacific Marine Environmental Laboratory in October 1992 following a destructive tsunami in Nicaragua. In October of 1996 management of the TBB was transferred to the ITIC. The TBB provides a means for the community to rapidly exchange information on recent tsunami events. Once they have fulfilled their requirements for message dissemination to the emergency management community, the United States Tsunami Warning Centers routinely copy their warning, watch, or information messages to the TBB for the tsunami community. The ITIC Director would like to see Tsunami Warning Centers in other Member States initiate a similar practice. This may give tsunami researchers a chance to implement some tsunami characterization strategies BEFORE the tsunami actually arrives in their localities. The TBB, of course, will continue to be a means by which those interested in organizing post-tsunami surveys can reach those interested in participating in such surveys. The TBB is meant to be the place where one can go for "late breaking" information on tsunamis, tsunami studies, and developments in the tsunami community.

The ITIC web site, http://www.shoa.cl/oceano/itic/frontpage.html, is the next level of tsunami information dissemination. The ITIC web site provides the web browser with information on the purpose of the ITIC as well as the Tsunami Warning System in the Pacific. It also directs the browser to other sites that contain the results of tsunami investigations and other information about tsunamis, as well as to sites announcing tsunami meetings and workshops. The ITIC will keep on the web site a continually updated list of earthquakes in the Pacific basin above a 6.0 magnitude so that tsunami investigators may have a chance of recovering data from even very small tsunamis, if available. For earthquakes over magnitude 6.5 there is a second list of Pacific basin earthquakes that provides the browser not only with earthquake parameters but also information on actions taken by the Tsunami Warning System in the Pacific regarding the

earthquake. The web site is meant to be a place where one can find a summary of information on recent tsunamis or links to sites providing reports on investigations of recent tsunamis. The ITIC established its main web site in the summer of 1998. Through the generosity of the Chilean Hydrologic and Oceanographic Service, (SHOA), the web server is located in their main facility.

With these two means of tsunami information dissemination in place, the Director decided to consider alternatives to the semiannual publishing schedule of the "Tsunami Newsletter." The last Newsletter while dated January 1997 was actually released in September 1997. Was this really a "news" letter? Tsunami "news" can now be readily found on the TBB and the web site. It is true that a number of subscribers to the "Tsunami Newsletter" may not have access to these electronic sources of tsunami information but the ITIC feels that significant number of the Newsletter subscribers can access the web site or subscribe to the TBB. The ITIC may conduct a survey on this matter later this year. There are about 800 subscribers to the Newsletter and about 250 subscribers to the TBB at the present time. Therefore the ITIC is considering publishing only one hard copy publication per year or perhaps one major hard copy publication and a number of smaller "newsletters" per year. Publication and postage charges would be the main factor involved in choosing between these options.

The major hard copy publication could take the form of an almanac or yearbook. It would contain summary information on the Tsunami Warning System in the Pacific over its entire existence such as current and past Member States, Officers, National Contacts, meeting sites, visiting experts, and so forth. It would contain information on major tsunamis that have occurred during the existence of the Warning System and actions taken by the Warning System during or following the events. It would also provide detailed summaries of information for the year just prior to its publication. It would have a publication deadline of no later than March 31 every year.

The smaller newsletters could be printed as a simple 4-page fold over of a standard US 11x17-inch paper size. Most of the material in these newsletters would be taken directly from the web site and the TBB. In-house desktop publishing methods would be used to produce these newsletters. They could fill the gap for those who do not have access to the web or the TBB.

The next issue of the "Tsunami Newsletter," which will be published in the next few months and cover events in 1998, will be somewhat of a preview of the yearbook form described above. Whatever decisions are made at the ICG/ITSU meeting in Seoul, Korea, this October, a hard copy publication summarizing the Seoul meeting and all 1999 tsunami events will be published before March 31, 2000.

Michael E. Blackford
International Tsunami Information Center

Australia

Australia has continued to develop its tsunami warning capabilities in the intersessional period since ITSU-XV, through strengthened coordination and liaison across operational and response agencies. There has been continued progress toward developing an Australian Tsunami Warning System (ATWS).

The ATWS has been more specifically focused on providing tsunami warnings for Australia's Indian Ocean coasts, where the warning activities of ITSU do not apply. The economically significant offshore oil and gas industry and associated coastal facilities, which are located on the northwest ocean margin of the continent, are known to be at risk of major damage from tsunamis that may be generated in the Indonesian arc. Government and industry are directing resources toward researching the magnitude of the hazard posed by tsunamis in that region. Cooperation of operational agencies is enabling monitoring and response actions to be placed on a more operational footing, providing for the first time basic intelligence on tsunamigenic seismic events likely to affect Australia's western coastlines.

A further objective of the ATWS is to improve tsunami warning capabilities for Australian Pacific coastal regions. With increased commitment to monitoring both seismic activity and ocean sea level response generally, the ATWS will also boost tsunami monitoring, prediction, and warning capabilities in Australia for coastal areas now covered by the PTWC's area of responsibility.

Tsunami Events

Tsunamigenic earthquakes in the Australian region occurred on 17 February 1996 along the north coast of Irian Jaya and on 21 April 1997 in the Santa Cruz Islands. More than 100 people were killed and extensive damage was wrought on Biak and the north coast of Irian Jaya in the magnitude Mw 7.9 earthquake there. No reports of damage or injuries were received in Australia following the Mw 7.5 earthquake in the Santa Cruz Islands but a small tsunami was recorded on tide gauges in eastern Australia.

Tsunami Meetings

A Tsunami Workshop was held in Brisbane in July 1996, in conjunction with the Western Pacific Meeting of the American Geophysical Union. A meeting of the IUGG Tsunami Commission was held in Melbourne in July 1997, as part of the 1997 Joint IAMAS/IAPSO Assemblies. These meetings have fostered continued interest from scientists, response agencies, and operational agencies such as the Bureau of Meteorology, in evaluating the tsunami hazard and risk in Australia. They have also assisted in formulating plans to provide national warning and response strategies commensurate with those risks.

Liaison with PTWC and ITIC

Mr. Phil Parker, National Coordinator of Marine Weather & Oceanographic Services in the Bureau of Meteorology, visited both the PTWC and the ITIC in March 1997. The visit provided close-range familiarization with the operational activities of the PTWC and the ITIC; including useful dialogue on how tsunami-response information from Australia could be further utilized by the Centers.

Tsunami Research Activities

A major tsunami-related research project relevant to ITSU tsunami monitoring activities that has been in progress is a Ph.D. dissertation, "The Tsunami Threat to Australia", by Mr. W. Mitchell, Deputy Director of the National Tidal Facility. This work concentrates on tsunamigenic events in the Indian Ocean area to the north and northwest of Australia and includes the characteristics of generation, propagation and inundation of tsunamis in that region, and particularly the impact on Australia's northwest coast. A finite element hydrodynamic model is being used to determine the response to tsunamis generated from a variety of locations. Efforts to carry out higher resolution modeling studies of inundation of some local embayments in northwest Australia are in the planning stage.

Another major project is the research by the Australian Geological Survey Organization (AGSO) into the character of tsunamis of different tectonic origin. This research has been facilitated by the recording in Rabaul Harbor, Papua-New Guinea of tsunamis from tectonic earthquakes, volcanic earthquakes, and volcanic ash flows into the harbor during the 1994 eruptions of Volcan and Tavurvur volcanoes. Early results were published in the proceedings of the IUGG Tsunami Commission Symposium held in Melbourne in July 1997.

The AGSO and the Natural Hazards Center have established an Oracle Relational Database of Tsunamis at Macquarie University focusing particularly on the Australian region. Some of the more important analog tidal gauge recordings of tsunamis have been digitized and tabulated in the database and a dynamic link has been established to the AGSO World Earthquake Database.

A multidisciplinary project coordinated by Dr. Jack Ryan to assess tsunami risk and implications for early warnings in Australia is nearing completion. This project has:

* assessed the tsunami hazard in Australia and its territories;
* identified tsunamigenic sources in the broad area likely to affect Australia;
- developed travel time charts for areas of significance;
- identified built areas at risk;
- prepared a practical guide to tsunami risk for use by planning authorities, disaster management, and management of the tsunami warning system; and
- identified future research projects in the area.

The project has been sponsored by the Australian IDNDR committee, with primary carriage and further funding coming from the Bureau of Meteorology and the Centre for

Earthquake Research in Australia. Additional support has been provided by the AGSO, the Police and Emergency Services in Queensland, the National Tidal Facility (NTF), the Emergency Management Australia and university geophysicists. Elements of the report of this project are expected to be published during the next 12 months.

Development of the ATWS

Operational linkages between the Bureau of Meteorology's Regional Forecasting Centre (RFC) in Perth, Western Australia, and the AGSO Seismological Centre have been established which enable the Bureau to obtain real-time notification of likely tsunamigenic seismic events relevant to warning activities along Australia's continental Indian Ocean coasts. Plans have been devised to regularly test the system in-house, and with the involvement of relevant external recipients likely in the near future.

The ATWS utilizes the AGSO Tsunami Warning and Earthquake Alert System which is being prototyped using a system operating off seismograph networks developed by RMIT University in South Eastern Australia. Successful tests of the systems developed by RMIT, to access the AGSO National Telemetered Seismograph Network, have been conducted. The final system should soon be fully operational with backup provided by regional networks in Western Australia, South Australia and the current system in southeastern Australia.

The departure of Dr. Tad Murty, former Director of the NTF, caused some operational difficulties, but these have recently been overcome. This has enabled planning to proceed for installation of a new tide gauge on Christmas Island, and for full operational integration of the NTF in its role of providing sea-level response monitoring and interpretation capabilities for the System in accordance with national planning arrangements.

As a result of the creation of operational communications links between the Bureau of Meteorology and the AGSO, and the development of operational arrangements within the NTF, the Bureau's RFC in Perth issued a new Tsunami Warning Directive for the Western Australian region. The Directive provides Bureau of Meteorology forecasters with background scientific support on tsunamis, plus detailed procedures and information about need-to-know agencies requiring warnings in the event of a tsunami.

Links to emergency response and other government agencies and industry have been strengthened through their participation in recent symposia held in Australia, and via more formal working groups and meetings that have been held at State level. Interest in extending the operational trial of the ATWS to the eastern (Pacific) coast of Australia is strong, with an in-principle agreement for arrangements operating in Western Australia to be extended to Queensland. These arrangements will be modified to account for the lead role of the PTWC in monitoring- tsunami generation and response in the Pacific.

Canada

Tsunami Warning Water Level Stations

The Canadian Hydrographic Service (CHS) presently operates three tsunami warning stations on the British Columbia (B.C.) coast in support of Canada's contribution to the Pacific Tsunami Warning System:

Bamfield Tsunami Warning Station

This station was in continuous operation during the reporting period. Both a digital data logger and an analogue recorder are operated at this station. The digital data logger, otherwise known as the Tidal Acquisition and Telemetry System (TATS), is accessible by telephone line using a computer with modem attachment. Both PTWC and ATWC are able to access this gauge.

Winter Harbor Tsunami Warning Station

This station was in continuous operation during the reporting period. The station presently has a digital data logger (TATS) and an analogue recorder. The TATS gauge is accessible directly by either PTWC or ATWC.

Langara Island Tsunami Warning Station

As noted in the report presented at ITSU-XV, repairs to this station have become increasingly difficult due to a scarcity of parts and technical expertise. In the fall of 1995, attempts were made to repair the recorder at the light station, but this attempt failed, so the analogue recorder at the gauge house (1 km from the light station) continues to be the only source of observed water level information. This information is obtained by VET radio with the assistance of a gauge attendant.

No significant tsunami was observed at any of these stations during the reporting period. Notification of all communication tests initiated by ATWC, as well as summaries of these tests, is received by the CHS on a regular basis.

The government of Canada is proceeding with plans to automate most of the lighthouses on the British Columbia coast. At present, no decision has been made regarding the light station at Langara Island. If the station is automated, new tsunami warning equipment will have to be installed almost immediately, or a new station will have to be established at Rennell Sound or some other location near the north end of the Queen Charlotte Islands.

In 1996 the Canadian Hydrographic Service requested priority funding to upgrade its three tsunami warning stations by installing new data loggers at these sites and transmitting, the data directly to the Institute of Ocean Sciences using Mobile Satellite (MSAT) communication. This proposal was approved in early 1997, and the required hardware and software is now ready and waiting Department of Communications approval to begin the communication tests. This project will be reported on in greater detail at ITSU-XVI.

Regional Preparedness

The Provincial Emergency Program (PEP) has a Tsunami Warning Plan for the B.C. coast. In this plan, the Canadian Hydrographic Service is tasked with providing information on tsunami from stations on the B.C. coast, and with providing forecast information based on results of numerical model simulations, data obtained from other stations (provided by PTWC and/or ATWC), and tidal predictions.

The recent transfer of responsibilities for tsunami warning in the northeast Pacific to the Alaska Tsunami Warning Center (ATWC) in Palmer, Alaska has resulted in improved efficiencies and reduced duplication of effort. Canada, through PEP, along with the state governments of Alaska, Washington, Oregon and California, continues to work closely with the ATWC to improve tsunami response in the northeast Pacific.

The CHS's tsunami response, in support of the Provincial Emergency Program, is provided by a core staff of three individuals who can be reached by telephone or pager at any time and provide the initial response and decision making advice. In support of that role the CHS contracted with a private company to improve its tsunami response documentation. A package was developed using FrameMaker for use on a Macintosh computer. Hypertext links allow fast access to information at a level of detail necessary to carry out the appropriate response. This package was demonstrated at the Pan Pacific Hazards '96 conference in August and received a very favorable response. In addition, PEP has been instructed to contact the CHS whenever an earthquake of magnitude 6.5 or greater is observed anywhere in the Pacific. These communication tests have been extremely useful.

During the last two years the Provincial Emergency Program carried out one test of its Tsunami Warning Plan. This test, designated Seaswell IV, was the first test where the date and time had not been previously publicized.

Regional response to earthquakes, tsunami, and other emergencies is coordinated, in part, through meetings of the B.C. Earthquake and Tsunami Working Group and the B.C. Regional Emergency Telecommunications Committee. The Earthquake and Tsunami Working Group met in February 1997 after several years of inactivity. The Western States Seismic Policy Council will meet in Victoria in November and will have a session on tsunami.

ITSU and IOC Activities

Canada continues to be supportive of ITSU activities, but is finding it increasingly difficult to allocate the required resources. Survey equipment developments (GPS etc.) continue to be monitored for suitable post-tsunami survey instrumentation and software, and communication technologies (satellite) continue to be monitored with regard to the communication requirements of the tsunami warning system. Funding was not obtained to support the printing of the Earthquake and Tsunami textbooks, and the possibility of funding support in the future is very unlikely.

International Decade for Natural Disaster Reduction

Two international conferences of note were held in Canada in 1996:1) Hazards '96 Conference in Toronto, Ontario July 24 - 28.2) Pan Pacific Hazards '96 Conference in Vancouver, B.C. July 29 - August 2.

The CHS had a display on tsunami hazards and tsunami response at this conference.

Tsunami Research and Development

Much of the research in Canada at present focuses on tsunamis generated by Cascadia Subduction Zone earthquakes (see publications of interest.) In support of studies being carried out by the Pacific Geoscience Centre (Sidney, B.C.) to monitor crustal deformation on Vancouver Island, the CHS has for the past 15 years maintained a network of twelve water level stations to obtain information on rates and trends of sea level change. Due to budget reductions, many of these stations are now being removed from service. The CHS has, however, confirmed the importance of tsunami warning and will continue to maintain the necessary stations for this purpose on the B.C. coast.

Training and Education

In the last few years there has been compelling evidence that megathrust earthquakes occur along the Cascadia subduction zone, and that the last of these earthquakes may have occurred in December 1700. These finding have produced a great deal of interest. Much of the public education for earthquake preparedness is provided by staff of the Pacific Geoscience Centre, and experts from the Institute of Ocean Sciences regularly provide information on tsunamis and tsunami response to researchers, schools, insurance industry representatives, and the general public. As part of the public education program, all telephone directories for communities in B.C. coastal areas contain information on earthquake and tsunami response.

Publications of Interest

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CHILE

Introduction

This report summarizes the activities of the National Tsunami Warning System, during the period since the Fifteenth Session of the ICG/ITSU held in Papeete, Tahiti, and French Polynesia, between 24-28 July 1995, until August 1997. The head office of the National Tsunami Warning System is at the installations of the Department of Oceanography of the Hydrographic and Oceanographic Service of the Chilean Navy (SHOA). SHOA is responsible for issuing a tsunami warning in Chile.

During the intersessional period several tsunamigenic earthquakes of far field were recorded in Chile by "El Roble" TREMORS Station. Since the Antofagasta event in July 1995, no other local tsunamis have been detected or reported in this period.

Latin American Training Course on Numerical Tsunami Modeling

As an international co-operative effort to transfer tsunami modeling technology, under the auspices of the TIME (Tsunami Inundation Modeling Exchange) Project and support from IOC and CICESE, SHOA carried out a two-month intensive training course on numerical tsunami modeling from 8 March to 3 May 1996. It was taught in Valparaiso, Chile by Mr. Modesto Ortiz, M.S. Oceanography, associated with the Centro de Investigacion Cientifica y de Educacion Superior de Ensenada (CICESE, Mexico).

The course was based on the Tohoku University Numerical Analysis Model for Near-field Tsunamis Research. It was given in Spanish and participant experts were: Mrs. Patricia Arreaga, Oceanographer, from Instituto Oceanografico de la Armada del Ecuador; Mr. Fernando Urenna, Meteorologist, from Servicio Mareografico y de Estado del Mar de Costa Rica; Mr. John H. Caicedo, Computing Engineer, from the Observatorio Sismologico del Sur Occidente de Colombia and Mrs. Carolina Martinez, Geographer, Mr. Dante Gutierrez, Oceanographer and Mr. Francisco Leiva, Computing Engineer, from Servicio Hidrografico y Oceanografico de la Armada de Chile (SHOA).

Course on the Usage of TREMORS

A one-week course on the usage of TREMORS System for earthquakes and tsunamis detection was conducted from 6-11 May 1996, in Valparaiso, Chile, at SHOA. It was taught by Dr. Francois Schindele, associated with the Centre Polynesian de Prevention des Tsunamis (CPPT). The course was given in Spanish, taking part in it, in addition to the experts participating in the Latin American Training Course on Numerical Tsunami Modeling, were Mr. Salvador Farreras and Modesto Ortiz from CISECE, Mexico.

CITSU Project

Since the Latin American Training Course on Numerical Tsunami Modeling was completed, SHOA has been working actively in the CITSU Project, "Processing of Inundation Maps by Tsunamis for the Chilean Coast". This is a 5-year Project. The first maps during 1997 will be the ones of 3 largest cities in the northern part of Chile; namely Arica, Iquique and Antofagasta. As it is well known, the two northern most cities

are located in a "seismic gap" zone. Inundation maps will be used for tsunami hazard planning by the national civil protection agency (ONEMI) and other government institutions.

Several seminars in Oceanography, Earthly Sciences and Natural Disasters, organized by government and private institutions of the country, all of them during 1996 and 1997, have had a special chapter to show this Numerical Tsunami Modeling Technology and its applications in Chile.

Tsunamigenic Earthquake Detected by the "El Roble" TREMORS Station

As already reported at the IOC/ITS-XV meeting (August 1995), in Chile is operating the TREMORS, a seismic monitoring system designed to estimate the tsunami risk. During this period, SHOA has been working actively in the analysis and processing of the seismic information obtained.

Regarding the agreement reached with the Peruvian Navy to exchange tsunami information originated by earthquake activity in Peru-Chile, the events of 21 February 1996 in Chimbote and 13 November 1996 off Nazca, both off Peru, were quickly reported. The tsunami waves generated by these events were recorded as far south as Caldera and in Easter Island.

Preparation for the International Conference on "Modern Preparation and Response Systems for Earthquake, Tsunami and Volcanic Hazards", 27-30 April 1998, Santiago, Chile

On the occasion of the XXI General Assembly of the International Union of Geophysics (IUGG) in Boulder, Colorado in June of 1995, Chile was proposed as host of a major IDNDR conference. The purpose of the conference was to highlight the ability of modem technology to lessen the risk in large urban and industrial areas caused by earthquakes, tsunamis and volcanoes. The co-sponsors are the International Association of Seismology and Physics of the Earth's Interior (IASPEI) and the International Association of Volcanology and Chemistry of the Earth's Interior (IAVCEI). The organization of this meeting is being carried out by a national organizing committee, composed by representatives of several Chilean and international institutions and programs. Chairman ICG/ITSU, Captain Hugo Gorziglia, was invited to be part of this local organizing committee.

The 1998 Conference will be organized to ensure working interaction among scientific, engineering and emergency service professionals, and is planned to respond to the United Nations' call for all governments, universities and private organizations to strengthen their IDNDR activities on natural disaster reduction. The emphasis will be on information dissemination and risk reduction.

Themes proposed are:

- Instrumental Recording System Status (Earthquakes, Tsunamis and Volcanoes);
- Data Acquisition State of the Art Technology;
- Rapid Assessment of Hazards in Urban Areas (strong ground shaking tephra falls, ocean run-up);
- Rapid Failure Evaluation for Critical Structures and Lifelines;
- Near Real-Time Emergency Response;
- Early-Warning Satellite Systems for Monitoring Seismic, Tsunami and. Volcanic Hazards;
- Integration of Dissemination Technology and Disaster Mitigation Plans.

ICG/ITSU and IOC will explore their support and participation in this meeting. Some kind of auspices could be given to invite some experts on these topic

Memorial

Dr. Lautaro Ponce, Seismologist, Chilean expert in earthquakes and tsunamis from the Department of Geophysics, University of Chile, Chief of the National Seismological Service, was part of the National Tsunami Warning System and Chilean representative at the IOC Tsunami Programs as scientific part of the Chilean team of quick response missions to tsunami affected areas. Mr. Ponce passed away on 25 November 1996. We will not forget his diligence, professionalism and friendly personal manner.

France

Introduction

Since 1995, the Laboratoire de Géophysique (LDG) has been improving the development and implementations of the TREMORS system. LDG was also involved in numerical simulations of tsunamis induced by earthquakes and tsunamis produced by submarine landslide. In Marquesas Islands, several tsunamis were observed : the 31 July 1995 Chilean tsunami and the 21 February 1992 Peruvian tsunami. Both generated important waves (2 to 4 meters high) in the Hiva-Hoa Tahauku bay and some damages were produced in several other area.

TREMORS System

New Stations:

Several new stations have been implemented, one in Chile (ELRO), in Indonesia, in Brunei, in Madeira Island (GITEC-TWO EEC project), in Mongolia and another one in French Polynesia.

Software improvement : Adaptation to MINI-SEED IRIS Station

The TREMORS software has been adapted to the IRIS real-time format (MINI-SEED, 5Hz serial line) with the cooperation of PTWC and IRIS. The TREMORS software is operating in PTWC in Hawaii since November 1996, using the data of the KIP IRIS and GEOSCope seismic broad-band station. A new feature is that the system and signal processing work directly on ground velocity (the output of the Streckeisen STS1 seismometers, is velocity instead of displacement like LDG instrumentation).

Recent Activities of LDG Concerning Numerical Simulations

Numerous tsunami simulations were undertaken by LDG during 1995-1997. LDG is involved in the study of both tsunamis produced by submarine landslides and tsunamis induced by earthquakes. Numerical simulation of tsunamis in the Pacific Ocean, in Europe and in the Caribbean Sea are presented in this report.

Pacific Ocean:

On the 30th July 1995, an earthquake with magnitude of 8.1 occurred off the coast of Chile. Although earthquake damage was widespread, tsunami run-up rose a few meters above sea level at most and caused only insignificant damage along the Chilean coast. 13h 30 min later, the tsunami reached the Marquesas Islands (French Polynesia) and particularly Hiva-Oa where wave heights of about 3 to 4 meters were observed in the harbor of Tahauku Bay. Some boats were swamped and sank in an eddy behind the breakwater.

The ground deformation has been calculated using Okada's formulas (1985) based on the seismic parameters determined by Ruegg and Manfret.

The high waves observed in the Marquesas Islands seem due to local effects and not to the gradual submarine slopes ranging from 5° to 10°, steeper than the ones of Hawaii. The other archipelagos of French Polynesia (Gambier, Society Islands, Austral Islands or Tuamotu) present steep slopes around 30° and were not affected by this tsunami. In order to study the effects of local bathymetry, coupling between coarse and fine grids has been carried out in the island of Hiva-Oa, where one of the most violent phases of the tsunami was filmed during about 10 min showing the Bay of Tahauku and its small harbor. The length of this Bay is about 1 km, the width at the mouth is about 500 meters. At its maximum level, the tsunami penetrated about 250 m the mouth of Tahauku River and inundated 40,000 m of land.

The numerical simulation of these phenomena in the harbor of Tahauku Bay has required the coupling between four grids. The finest grid increment is 10 m in the fourth grid covering the Bay of Tahauku. The computed maximum and minimum sea levels match very well the observations as regards the maximum crest-to-trough wave heights close to the breakwater and the maximum run-up and run-down distances. The breakwater plays the part of a dam when the sea level withdraws, the sea level outside the harbor is lower than inside. The observed large eddies generated by the breakwater are also well reproduced by the model.

Europe:

The following activities have been carried out within the framework of an European project named GITEC-TWO (Genesis and Impact of Tsunamis on European Coasts - Tsunami Warning and Observations). The other participants of this project are the Universities of Athens (Greece), Genoa, Bologna and Rome (Italy), Oslo (Norway), Lisbon (Portugal) and Coventry (Great Britain). Two of these activities are: the simulation of potential landslide-generated tsunamis in Italy and the simulation of the 1755 Lisbon tsunami.

Caribbean Sea:

The Soufriere Hills volcano, in the island of Montserrat (Caribbean Sea), has been erupting since July 1995. 10 people have been killed by a debris avalanche on 25th June 1997. The evolution of the volcano activity could lead to the collapse of a portion of the lava dome and to a sudden entry of debris avalanche into the Caribbean Sea. In the worst case scenario, the volume of material reaching the sea has been estimated at 80 millions of cubic meters. The aim of this paper is to assess the hydraulic phenomena in the Caribbean Sea related to this potential aerial landslide on Montserrat.

The sliding of this mass and the generated water surface have been simulated numerically. The numerical model solves the 3D Navier-Stokes equations for a mixture composed of sediments and water. The generated water waves is propagated by means of shallow water models around the coast of Montserrat and in the direction of Guadeloupe, located at a distance of 55 km of Montserrat. The numerical results show that wave heights could be as high as 10 meters on Montserrat coasts within a radius of 2 km of the landslide impact. Waves reach Guadeloupe after about 10 minutes with amplitudes ranging from 1 to 2 meters.

Tsunami Observations in French Polynesia

In 1995 and 1996, 3 far field regional tsunamis were observed in Marquesas Islands, specially in Hiva Hoa Tahauku bay. The first and highest one happened at the end of ITSU XV (30 July 1995), generated by the Chile earthquake. This 8.1 Mw earthquake resulted in the issuance of a regional tsunami warning

and watch for the southeast Pacific by the Pacific Tsunami Warning Center. After several hours the alert was canceled based on the relatively small waves having been observed along the Chilean coast. Eleven hours after the quake, a series of 5 waves, the first of which was 3-4 m high, came into the Tahauku bay at Hiva Hoa, sinking two small boats and damaging others. This was the only damage reported outside of the source area. The unusually large waves at the Tahauku bay and from the October 9 1995 Mexico earthquake have prompted our Centre Polynésien de Prévention des Tsunamis to lower its threshold for issuing warnings for this bay (Mo < 8.0 E+20 Nm from East Pacific and 5.0 E+21 Nm from North and West Pacific).

A comparable tsunami was observed in the Tahauku bay eleven hours after the 21 February 1996 Peruvian earthquake. This was a « tsunami earthquake » no felt by coastal communities (as the 12 September 1992 Nicaragua earthquake and the 2 June 1994 Java earthquake). The mb magnitude of this event is only 5.8 and the moment magnitude Mw 7.5. This earthquake produced a tsunami of 148 cm wave height in Chimbote and between 2 and 5 meters of run-up. Several waves were seen in the Tahauku bay , the first of which was 2-3 meters high and some damages observed in several bays in other islands.

These 3 events demonstrate that when a tsunami of amplitude greater than 2 meters happen in Central or South America, this tsunami will generate several waves of more than 3 meters in far field in the Tahauku bay between 9 and 11 hours later. This is a very important observation for the far field warning and watch. In the future, when such tsunami of more than 2 meters high will occur in Central and South American West Coasts, it is necessary that the countries who have detected or observed such waves send a warning to CPPT indicating the waves height observed in the tide gage stations. The waves will arrive 9 hours after the quake and the warning must be issued 2 hours before the tsunami arrival.

Hong Kong

In Hong Kong, the Hong Kong Observatory (HKO) operates a tsunami warning system. This comprises a seismic monitoring network of long and short period seismometers to detect earth tremors and 9 tide gauges to report sea-levels at selected locations in Hong Kong. Communication links were set up to connect HKO with the Pacific Tsunami Warning Centre (PTWC) through the Global Telecommunication System (GTS) on one hand, and the Information Services Department (ISD) of the Hong Kong Special Administrative Region Government on the other. Detailed operational procedures have been set up whereby tsunami warnings will be disseminated to the public through ISD whenever a tsunami is expected to affect Hong Kong.

The local seismic monitoring network was upgraded to a fully computerized system in 1997. The network was also expanded from 3 to 8 seismological stations. This system utilized advanced digital techniques for real-time data transmission and processing. The use of computer workstations and user-friendly software enhance the efficiency and accuracy of seismic data acquisition and analysis. Also, real-time sea-level data from tide gauges will continue to be used for operational warning of sea flooding in Hong Kong, answering inquiries on extreme water levels and the preparation of tide tables.

Tsunami is not common in Hong Kong. A list of all measurable tsunamis arriving in Hong Kong are listed in the table below:

Tsunami Recorded in Hong Kong

Date	Origin	Earthquake Magnitude	Maximum Amplitude (peak to trough)
Nov. 1952	Kamchatka	8.2	0.15 m
May 1960	Chile	8.5	0.6 m
Mar. 1985	Chile	6.7	About 0.1 m
Jun. 1988	Luzon Strait	5.1	0.65 m

Japan

Tsunami Warning Operation by Japan Meteorological Agency (JMA)

JMA is a governmental authority that is responsible for nation-wide monitoring of seismic activities in and around Japan, and for issuing of tsunami warnings and provision of earthquake information to the public. JMA has six Regional Tsunami Warning Centers (RTWCs) at Sapporo, Sendai, Tokyo, Osaka, Fukuoka and Naha. JMA Headquarters has functions of Tokyo RTWC. As far as tsunamis occurring near Japan, each RTWC issues tsunami warnings to respective responsible coasts. The same information is sent to PTWC and to neighboring countries via GTS. JMA Headquarters is also responsible as the national center for issuing warnings to the whole Japanese coast areas for distant origin tsunamis that may affect the Japanese coastal areas.

Earthquake and Tsunami Observation Network

JMA continuously monitors seismic activity all over Japan by the seismograph network. The seismic signals are transmitted to the computer systems (EPOS: Tokyo and EPOS: others) of the RTWCs from the seismic stations with on-line and real-time telemetering. Through the man machine method, tsunami warning or advisory is issued when necessary.

After the "Southwest Off Hokkaido Earthquake, 1993", JMA reconstructed its seismograph network that consists about 180 seismic stations. In 1996, JMA also intensified the tide gauge network and the number of tide gauge stations are increased to 77. These tide gauge data are continuously transmitted to RTWCs through the telemetering system to monitor tsunamis.

Advanced Tsunami Forecast Issuance Process

Reconstructed seismograph network and the newly adopted procedure of the P wave magnitude significantly contributed to determine the hypocenters and the magnitudes more rapidly. These resulted to shorten the time of tsunami forecast operations, and JMA is aiming to disseminate the tsunami warning or advisory within three minutes after an tsunamigenic earthquake.

In addition, for prompt sending message to the public, brief information regarding occurrence of a large earthquake is automatically superimposed on home TV screen on a real time basis. To reduce relay time of tsunami forecast from RTWCs to local governments and municipalities, " Satellite-based Emergency Information Multi-destination Dissemination System " is operated. This system has the function to back up the functional disorder on the land-line based communication system.

Real Time Exchange of Tide Gauge Data

Japan and the United States promoted the mutual exchanges of tide gauge data, and the data exchanges of six tide gauge stations in Aleutian, Alaska, Philippines and Micronesia region are operational. In 1997, the tide gauge data at five stations in Japan and nine stations in the mid-Pacific islands and the west coast of the United States are being transmitted to the United States and Japan. JMA will promote further the data exchange between Japan and the related organizations.

Tsunami Inundation Modeling Exchange (TIME)

The TIME started in 1991 and the Disaster Control Research Center (DCRC), Tohoku University, Japan has been significantly acting as the center to transfer a numerical technique of tsunami simulation, TSUNAMI, to the countries which suffered or will suffer tsunami hazards. During the period of 1991-1997, fifteen persons of fourteen institutions of eleven countries obtained - are obtaining the computer programs and manuals developed and prepared by DCRC. Tsunami simulations are successfully accomplished by the trainees after their returns in several countries.

The transfer of the TSUNAMI codes and manuals are available on request. DCRC will also continue the efforts in the next phase of the project, TIME-Second Phase, acting as the center.

New Tsunami Forecast with Numerical Modeling; Under Planning

JMA developed a new scheme of tsunami forecast using a data-base of the arrival times and heights of tsunamis for tsunamigenic earthquakes with various magnitudes and depths of the fault planes around Japan, that are calculated with the numerical model. When a large earthquake occurs, the tsunami heights and arrival times on the specified coasts are searched from the data base with the computer system to conduct tsunami forecast. With this method, the extent of present tsunami forecast blocks will be reduced to the dimension of individual prefecture coasts with about several tens kilometers.

The operation is now under planning anticipating the start in spring of 1999.

Regional Tsunami Warning Center

In case of a tsunamigenic earthquake in the Japan Sea, it is technically possible to disseminate tsunami warning to neighboring countries, after the operation of the above-mentioned new tsunami forecast method. The background condition concerning the communications should be further persuaded among Japan and the related countries.

Regarding the NW Pacific Region, the technical conditions containing quick acquisition of seismic data from related countries should be confirmed. Therefore, the questionary survey addressed to the related national contacts will be conducted by JMA to investigate the feasibility for the operation.

Korea

The seismological services in Korea have had some changes for the past 2 years from 1995 to 1997. The main changes are (1) the establishment of the seismological division in the Korean Meteorological Administration (KMA) which is responsible for seismological services in Korea and (2) the upgrade of the speed of the World Meteorological Organization's Global Telecommunication System (GTS) between Seoul, Korea and Tokyo, Japan, and Seoul and Beijing, China which are used for exchange of seismological information among WMO Members.

The tsunami warning was given only one time in the southern coastal region of the Korean Peninsula in 1996 on account of the major earthquake with magnitude 7.9 occurred in the Irian islands, but any damage due to the tsunami was not reported. In 1995 and 1997, tsunami warnings and damages were absent.

The Establishment of Seismological Division

The seismological division in KMA was established in Janu-

ary 1996, so that seismological services could be performed more efficiently. Previously, earthquake services were performed by the meteorological observation division of KMA. The seismological division belongs to the Forecast Bureau of KMA. The main responsibility of the seismological division is to monitor earthquakes and tsunami in and around the Korean Peninsula and announce warnings to the public.

Local Seismicity

During the period from January 1995 to June 1997, there were 79 earthquake events in and around the Korean Peninsula. The largest one with a magnitude of 45 occurred in the Youngwol area. Most Korean people felt the trembling due to the earthquake. Recently, the number of earthquake events tends to be on the increase.

January 1995 - June 1997

Magnitude	5> M > 4	4>M >3	3>M > 2	Total Year
1995	1	10	18	29
1996	2	12	25	39
1997	-	4	7	11
Total	**3**	**26**	**50**	**79**

Seismological Network

The KMA has been running the seismological observation network with 12 vertical-component short period sensors.

The KMA is going to install GSN-type broad-band seismometers in order to enhance the observational ability. Three accelerometers have been installed and two are being installed.

Tsunami Information Communication

The communication of KMA with the Japan Meteorological Agency (JMA), Pacific Tsunami Warning Centre (PTWC), Alaska Tsunami Warning Centre (ATWC) and other foreign countries is carried out through the WMO's GTS. The communication speed of the GTS between Seoul and Tokyo was upgraded to 64 Kbps from 9,600 bps in March 1997. Its speed between Seoul and Beijing was upgraded to 9,600bps from 4,800bps in June 1996.

When a large earthquake occurring in the nearby sea of Korea is recorded, KMA sends TSUNAMI X messages to inform the P-arrival time at Seoul and to ask earthquake parameters with tsunami. We directly inquire additional information from the Matsushiro observatory, JMA via telephone or use Interment to get more tsunami information.

Activities For Tsunami Preparedness

JMA is doing the small scale research on the real-time tsunami warning system. The purpose of the research is to calculate the wave height, tsunami arrival time to coastal regions of the Korean Peninsula. The independent tsunami warning system will be developed by combining observation from broad-band seismometers and a simple simulation model.

Future Plans

KMA has a long-term plan for the enhancement of seismological services and tsunami warning. The first phase of the plan is to expand the seismological observation network in Korea. The major projects are the installation of (1) 31 short period seismometers, (2) 9 broad-band seismometers, and (3) 31 accelerometers by 1999.

The second phase is to introduce the computer system for earthquakes and tsunami analysis. The current seismological analysis is partly performed on a personal computer. The overall analysis for earthquake and tsunami warning will done on medium scale computer systems. In addition, the database for seismological services will be built.

KMA also plans to secure experts on seismology and tsunami. The number of staff will be doubled in 1998.

Mexico

ITIC Associate Director

In support of a permanent request made at several ICG/ITSU sessions, to fill the position of Associate Director of ITIC, Mexico presented its Representative to the IUGG Tsunami Commission, Mr. Salvador Farreras, as a candidate to the post, for the term April 1995 - April 1996. Mexico provided him with his full time salary and a sabbatical leave from CICESE. During his 12-month stay, Mr. Farreras was responsible, either directly or as an advisor, in the following scientific-technological and educational activities of the IOC Tsunami Program:

- development of standard methodology and procedures for post-tsunami field surveys, including a field guide,
- investigation on optimization of new telecommunication technology to expedite the reception of sea-level and seismic data in real-time via satellite,
- improvement of present tsunami database standards, data collection and dissemination,
- review and update of the Master Plan for the Tsunami Warning System in the Pacific,

- organization, cataloging and automation of the ITIC library,
- development of new technologies for low cost alternatives to current sea-level instrumentation,
- training of visiting experts from ICG/ITSU Member States,
- development and translation to Spanish of educational and awareness material related to tsunami preparedness and mitigation, and editing of the biannual Tsunami Newsletter,
- coordination of the efforts of Central American countries with Colombia and Mexico to establish a Regional Tsunami Warning System,
- coordination of, and provision of, advice to Chile and Mexico regarding their initiative to organize a Latin American Course on Numerical Modeling and Early Detection of Tsunamis.

Actions Taken In Response to ITSU-XV Decisions

Post-Tsunami Survey Field Guide

An ad hoc Working Group, chaired by the ex-Associate Director of ITIC, with representation from Australia, Canada, Colombia and Mexico, developed a draft version of the "Field Guide for Post-Tsunami Surveys. This document will be presented to the attendees at the ICG/ITSU-XVI Session for their consideration of final publication.

Tsunami Inundation Modeling Exchange (TIME) Project

Mr. Modesto Ortiz from the CICESE Research Center of Mexico adapted tsunami inundation models developed by the Disaster Control Research Center of Tohoku University, Japan, to a national CRAY super computer. He successfully accomplished a simulation of the 12 July 1993 Hokkaido tsunami, and the 19 September 1985 Michoacan (Mexico) tsunami, a small but recent and well-documented local event with a source in the Middle America Trench off the Mexican coast, as test cases. A simulation of the most recent, 9 October 1995, Jalisco-Colima tsunami was also performed. Computed runup values showed reasonable agreement with visually observed runup in several locations and with the Manzanillo tide gauge record.

Inundation patterns and water flows, by simulation of potentially threatening tsunamis, were obtained for the industrial ports and tourist resorts of Acapulco, Zihuatanejo, Lazaro Cardenas and Salina Cruz. These maps of past-tsunami cases and future eventual extreme inundation patterns, produced by this project, will be used for tsunami hazard planning, to minimize the loss of life and damage to property by the Civil Protection Government Agency (Director General) of Mexico.

Time Technology Transfer Training to Latin America

Mr. Modesto Ortiz taught a TIME course from 11 March to 11 May 1996 at the Servicio Hidrografico y Oceanografico de la Armada (SHOA), Valparaiso, Chile. Students from Chile, Colombia, Costa Rica, Ecuador and Mexico attended the course. Each participant selected a case of tsunami generation and inundation of a coastal community in his (her) own country to apply the computer modeling techniqués.

Mr. Ortiz gave the same TIME technology transfer course from November 9 - 20 1996 at the Department of Marine Sciences, University of Puerto Rico, Mayaguez, Puerto Rico. More recently, Mr. Ortiz also gave a lecture on numerical modeling of tsunami inundation at the Caribbean Tsunami Workshop, held in Puerto Rico, 8-10 July 1997.

Update of Mexican Tsunami Catalogue

In response to a recommendation made at the ICG/ITSU-XV, the Catalogue of Tsunamis on the Western Coast of Mexico, published in 1993, which covers local and remote tsunamis detected in Mexico from 1732 to 1985, was updated. No tsunami arrivals were registered on the Mexican coasts from 1986 to 199 1, either because no one arrived or the tidal gauge recorders didn't operate properly. The following 4 tsunami arrivals detected more recently served to update the Catalogue:

DATE	MS	EPICENTER	SOURCE AREA	RECORDING SITE	MAX. HGT. (m)
19920901	7.2	11.81N 87.35W	**Nicaragua**	Isla Socorro	0.29
				Cabo San Lucas	0.28
19950730	7.8	24.16S 70.79W	**Chile**	Isla Socorro	0.23
				Cabo San Lucas	0.10
19951009	7.6	18.90N 104.10W	**Mexico**	Manzanillo	2.00
				Cabo San Lucas	0.50
				Isla Socorro	0.20
				Barra de Navidad	5.10
				Melaque	4.50
				Cuastecomate	4.40
				La Manzanilla	0.40
				Boca de Iguanas	5.10
				El Tecuan	3.80
				Punta Careyes	3.50
				Chamela	3.20
				San Mateo	4.90
				Perula	3.40
				Pta Chalacatepec	2.90
19960221	7.8	9.60S 80.20W	**Peru**	sla Socorro	0.25

With the exception of Manzanillo, Cabo San Lucas and Isla Socorro, the heights reported for the 9 October 1995 tsunami were runups measured during the field survey performed 10 days after the event by a CICESE-University of Southern California international team. The most recent 11 January 1997 earthquake off the coast of Michoacan, Mexico (Ms = 6.8) did NOT produce any observed or recorded local tsunami.

Children's Tsunami Cartoon Book in Spanish

Following an offer made at the ICG/ITSU -XV, Mr. Farreras from CICESE, Mexico translated into Spanish the ITIC/I0C Children's Tsunami Cartoon Book. The translated text was provided to ITIC. Work is in progress to adapt the illustrations. The final document will be presented to the ICG/ITSU-XVI participants to consider its publication.

Regional Tsunami Warning System For Central America

In support of a recommendation made at the ICG/ITSU-XV regarding a Central American regional Tsunami Warning System, representatives of Costa Rica, Guatemala and Nicaragua were contacted to solicit their opinions on the matter. Interest exists in organizing a regional warning system, however, funding for this kind of initiative is very limited. A reasonable alternative could be to develop a regional proposal similar to the one presented by the South West Pacific countries to seek international financial help. It was suggested that a meeting should be held to discuss a concrete action, although funding for this meeting will also be required. A few sea-level stations are in operation in the region: at least 2 in Panama, 1 in Costa Rica and 1 in Guatemala. Nicaragua, Honduras and El Salvador do not have sea-level stations. Costa Rica is planning to install and equip 3 of them with real-time data transmitters; and Nicaragua will probably have one installed in Montelimar with the support of PTWC. There is not enough money in general, in the region, to maintain or modernize the instruments. A strong effort and international help will be needed to improve this situation. Several trials to send dummy messages from PTWC to Costa Rica and Guatemala via the GTS-KWDC and AFTN circuits were made, without apparent success. Information from some sources indicated that the GTS network was rendered obsolete and was very soon to be replaced by the STAR4-SAT real-time communication network covering the Caribbean, Mexico and Central America. It was suggested that PTWC should switch to this new and more modern system of communication.

Other Activities Related to the ITSU Program

Extension of Seismic and Sea-Level Networks, and PTWS Participation

The CICESE Research Center of Ensenada installed two broad band seismic stations around the Gulf of California to monitor earthquakes: one located in Bahia de Los Angeles and the other one in La Paz, BCS. CICESE continued acting as a dissemination agency for the PTWS, with communications through telephone, fax, and e-mail, although not operational in a 24 hours/365 days basis due to limitations in personnel, budget, and infrastructure. Manzanillo, Socorro Island, and Cabo San Lucas sea-level stations continued to operate. Action will be taken during 1998 to reconstruct Guadalupe Island sea-level station.

Establishment of a National Tsunami Warning System in Mexico

A proposal to establish a National Tsunami Warning System in Mexico was submitted in February 1997 to the Experts Advisory Committee in Geological Hazards of the National Center for Disaster Prevention (CENAPRED), a Government agency of the Secretary of the Interior (Secretaria de Gobernacion) for their consideration.

The key components for this proposed warningsystem are:

a) A Center of Operations;

b) A Telecommunication Network;

c) At least one broad band seismic station equipped with real-time transmission;

d) At least 6 sea-level stations equipped with real-time transmission;

e) Hardware and software for automate real-time data process of the signals from the instruments mentioned above;

f) Permanent connection to the PTWC to send and receive messages;

g) Trained personnel operating in a permanent basis (24 hours/day 365 days/year); and

h) Links with similar systems operating the Central American and Caribbean nations with the aim of organizing a future Regional Warning System.

After an extensive discussion of the proposal during the June 1997 Session of the Experts Advisory Committee, it was agreed that:

a) A more detailed study of the need, feasibility and operational infrastructure required for such a system is required;

b) The General Director of CENAPRED will send an invitation to those institutions more closely related with the subject (National Seismological Service, National Meteorological Service, Department of Hydrography of the Navy, CICESE, etc.) to participate in an Ad hoc Working Group to perform the study mentioned above; and

c) The activities of this warning system should be organized

in such a manner as to reduce operational, investment, and personnel costs to a minimum. Preference will be given to the option of organizing the system within the already existing structure of some of the participating institutions.

It is expected that by August 1997 the Ad hoc Working Group will be formed and starting the study of feasibility for the establishment of the national tsunami warning system. As soon as there is an outcome on this matter, we will inform to the ICG/ITSU.

Tsunami Home-Page in Spanish and Educational Materials

CICESE produced a Tsunami home page in Spanish in the WWW. It can be visited at:

http://www.cicese.mx/-loyasa/tsunami/. With the co-operation of the National Center for Disaster Prevention (CENAPRED) of the Mexican Government, the content of the home page was printed and edited as a 24-page booklet titled "Fasciculo of TSUNAMIS". 15,000 copies were printed and distributed among authorities and population of the Pacific ocean coast communities of Mexico. Several other brochures addressed to children, adults and authorities are under preparation. The videos "Learning from Earthquakes" (18 minutes) and "Identifying Tsunamis" (30 minutes), provided to ITIC by Japan, are in the process of being translated to Spanish and adapted to Mexico by CENAPRED, too.

ICAROS/IDNDR Roving Seminar

At a request and invitation from the IOC Ocean Services Unit, Mr. Farreras from CICESE participated and contributed to the discussions on tsunami warning systems for the Caribbean at the Third, ICAROS (IDNDR Caribbean Roving Seminar) held in Puerto La Cruz, Venezuela, 25-29 November 1996. The goals of the Seminar were to promote dialogues between decision-makers, the technical community, and the national leaders in the Caribbean countries. The themes covered were I. - Reduction of the Vulnerability, II. - Society and Communications, and III. - Caribbean Co-operation. A 30-minute presentation on the IOC Tsunami Program was made. At the end of the presentation, on behalf of ICG/ITSU, the participants were invited to establish closer links with ICG/ITSU. It was suggested that they do this either through their National Contacts for those countries who are already Members, or by direct request of their institutions or organizations like the Association of Caribbean States (ACS). The purpose of these closer links would be to start co-operation, and provide advice and support in their tsunami prevention activities. Copies of the Tsunami Newsletter, PTWC and ITIC brochures, Tsunami the Great Waves booklet, Children's Cartoon Book, and PTWS Master Plan were distributed among the most interested participants. Personal contacts were established with: the Co-ordination Center for the Prevention of Natural Disasters in Central America (CEPREDENAC), the Association of Caribbean States (AEC), the National Commission for Emergencies of Costa Rica, the National Disaster Co-ordination of Saint Lucia, the Foundation for Seismologic Research of Venezuela (FUNVISIS), and the Agency for prevention and Mitigation of Disasters of the Dominican Republic. Most of the participants became aware that the Caribbean basin is a region where tsunamis may happen and represent a real threat of devastating effects. The following needs, which coincide with IOC TSUNAMI PROGRAMS and goals, were explicitly identified in the Recommendations of ICAROS 196-.

1. Establish a regional register of persons qualified and willing to undertake POST-DISASTER SURVEYS, and draw up investigating and reporting procedures for carrying out these surveys, and disseminate the results regionally. Prepare an inventory of personnel specifying skill or qualification, as well as capability for specific tasks.

2. Establish or reinforce close links with international organizations, in the field of natural hazards;

3. Implement education and training programs as well as technical exchange programs for the community, technicians, and disaster management professionals; and

4. Develop hazard mapping for storm surge, flooding, landslides, earthquakes and TSUNAMIS.

For the Future it will be necessary to continue our efforts to co-operate in tsunami prevention activities with the Caribbean community, based on the needs already identified by themselves in ICAROS'96, through:

a) Encouraging direct involvement and initiatives of the present ICG/ITSU Member States in the Region: Mexico, Guatemala, Nicaragua, Costa Rica, and Colombia, and Member States that have territories or possessions: USA, United Kingdom and France;

b) Providing support (educational material, etc.) to the Association of Caribbean States (AEC) operational committees dealing with disasters, and other disaster management regional organizations, like CEPREDENAC, at their request;

c) Getting involved in the implementation of the Recommendations that came out from the Experts Consultation on Tsunami Hazard meeting pursuant to IOCARIBE-V.5 part B I) Resolution, that took place in Virgin Islands last May, and the plan formulated by the scientific steering committee so appointed; and

d) Providing information and advice, through ITIC, on tsunami prevention to individuals and institutions of the Caribbean, at their request.

Nicaragua

Production

Only after the strong tsunami that struck the Pacific Coast of the country on I September 1992, the Nicaraguan public, the authorities and the scientific institutions became aware about this special hazard for the, towns, villages, harbors and other installations at the coast of Nicaragua. About 170 people died in the 4- 10m high flood waves, and the material losses along all over the Pacific coast were high. There was no possibility for warning the people living in this area because there existed neither a seismic network nor a communication system or any organization prepared for emitting the alert message.

This situation changed in the last years. Nicaragua,) with the help of several other countries succeeded to establish a well-organized seismic monitoring network to improve the communication system and to build up organizational structures in the frame of a program for the prevention of natural catastrophes. These new technical facilities and organizational improvements are also being utilized for the development of a National Tsunami Warning System.

The scientific organization responsible for building up and maintaining the seismic and maereographic monitoring systems and for developing the scientific studies necessary for the establishment of a tsunami warning system is the Instituto Nicaraguense de Estudios Territoriales (INETER), a governmental institution. The Nicaraguan Civil Defence Organization is responsible for the education and information of the population, preparing measures of alert-t and rescuing in case of dangerous situations and for emitting alert messages to the population that could be affected by a tsunami.

The following describes the activities in the field of tsunami mitigation and preparedness carried out in 1995-97.

Seismic Network

The Nicaraguan seismic network, installed with funding from Sweden, Norway, Switzerland, Germany and the Nicaraguan Government has now 20 telemetric stations (short-period vertical components) transmitting their data in real-time to the computerized data processing center at INETER Headquarters in Managua. At the Managua Data Centre there are installed 3 component sets of short-period, middle-period seismometers and accelerometers.

A seismic broad band statical (Quanterra data logger and STS-2 three component seismometer) funded by the German Government was acquired and is going to be installed in 1997 as an autonomous station near the town of Boaco in the Nicaraguan mountain regions about 150 km far from the Pacific coast. Data access will be possible by high quality telephone links. This station in the frame of a tsunami warning system is thought to serve for the rapid magnitude determination of large seismic events.

The routine processing of seismic data is carried out on workstations (UNIX operating system) at the Managua Data Centre by qualified persons belonging to the Seismological Shift, which operates 24 hours a day. The data of strong events are processed and a short report (hypocentre, magnitude-origin time, map) is printed within about 10 minutes after the occurrence of the earthquake. Then, within another few minutes, this computer generated report is sent to a large number of institutions (Government, Civil Defense, Mass media), using an automatic fax server of the Nicaraguan telecommunications company. The computing facilities and the reliability of the centre were much improved in 1995 and 1996 installing additional SUN workstations.

In 1995-96, a seismic experiment was carried out in Nicaragua to collect data for the improvement of the underground velocity model, necessary for the location of earthquakes. The project included the temporal installation of 10 ocean bottom seismographs off the Pacific coast of Nicaragua, in March 1996.

Accelerometer Stations

With funding from the Nicaraguan Government, 12 accelerometer stations were acquired in 1996 and 1997. They are recently used in the frame of a microzonation study in Managua but will be distributed in 1998 in Western Nicaragua to form the National Acelerographic Network. The digital stations with high dynamic range and exact GPS timing will record locally but remote access is possible via telephone.

This network is mainly thought to provide data for seismic risk studies but some instruments would be integrated in the tsunami warning system. Additionally to the broad band station they would supply amplitude information in case of very strong earthquakes, when the short period stations get saturated.

Mareographic Stations

When the tsunami of 1992 struck the Nicaraguan Pacific coast there existed only 2 mareographic stations with registration on paper. These devices were irreparably destroyed.

INETER recently received funding from the Nicaraguan Government for building up a network of Cartographic stations to be installed at the Pacific and Atlantic coasts, in the lake of Nicaragua and the lake of Managua. In 1996, the number of 4 stations were acquired. Two of them will be installed in August 1997 at the harbors of Corinto and Puerto Sandino at the Pacific coast. The other two are destined for Bluefields at the Atlantic coast and for lake Managua. In 1997, another 3 stations will be bought. The stations have local digital registration, remote access via the Nicaraguan telephone or cellular telephone system is possible.

Communication System

With funding from Switzerland, a radio communication system was installed in 1995 and 1996 which connects the headquarters of the Civil Defense with the seismological data centre of INETER and with the most important towns and villages of the Pacific Region of Nicaragua, especially with the coastal settlements. This system permits voice communication, as well as the transmission of special pager codes. Acquired in the frame of the tsunami warning system, these facilities are also used in other emergency situations.

The voice communication system is generally used to transmit alerts, warnings, explanations and information that do not require very rapid actions of the population or authorities. The transmission or coded signals arc thought to serve for the remote control of sirens and other acoustic warning devices to enable an immediate alert of the coastal population after having detected a tsunami prone situation. These devices were partially developed and tested in Nicaragua and are planned to be installed in 1998.

The procedure in case of a strong shallow near earthquake beneath the Pacific Ocean is -thought to be the following: The seismologist on duty from his office at INETER would inform by radio or telephone the responsible official of the Civil Defense who would then have the task to emit the automatic alert code and to inform the authorities via radio and telephone.

Information to the Population

In co-operation of several Nicaraguan institutions, a tsunami-related poster was elaborated and distributed to inform the population about the tsunami risk. Several publications in local journals and newspapers, conferences, seminars and TV discussions were utilized to explain the tsunami hazard in Nicaragua which can be considered a new theme for most people in comparison with the volcano and earthquake related risk.

On 1 September 1997, the fifth anniversary of the Nicaraguan tsunami of 1992, memorials will be inaugurated in co-operation between INETER and local authorities in places which were most heavily struck by the tsunami.

International Co-Operation

The 1992 tsunami impulsed Nicaragua to become member of the International Tsunami Warning System in the Pacific Ocean. Recently, the facilities for receiving tsunami warning messages via fax were improved. INETER has expressed its will to co-operate within the system exchanging seismic (readings or waveforms) and mareographic information, in real or near real-time. The Institute would he interested and able to maintain digital sea-level stations linked via Satellite to the headquarters of the Pacific Tsunami Warning System.

Nicaragua actively supported the discussion in the Central American Countries about forming a Regional Tsunami Warning System.

National Tsunami Warning System

The Nicaraguan Tsunami Warning System is still under development. Plans of responsibility and decision making, implementation of a formal legal base for the system, further training of personnel at all levels, improvement of the technical and seismological or scientific base, education of the population are topics of the development programs of INETER, Civil Defense Organization and authorities at several levels.

On 1 September 1997, the fifth anniversary of the 1992 tsunami, a preliminary phase of the Nicaraguan Tsunami Warning System is going to be inaugurated. This phase is thought for testing all the developed technical seismological systems and organization structures under real conditions.

Russian Federation

Introduction

This report summarizes the activities of the National Tsunami Warning System (NTWS) of Russian Federation during the intersessional ITSU period from 1995 to 1997.

Structure and Activities of the National TWS

The structure and principles of activities of the National TWS were described in National Report, presented at the ITSU-XV Session, and they have not been modified during the intersessional period. NTWS into the Russian System for warnings and activities in extraordinary situations (Russian Ministry on Emergency - RME), as a functional subsystem. At the same time the Russian Federal Service for Hydrometeorology and Environmental Monitoring (Roshygromet) continues to perform the responsibility for tsunami warnings and supervise development and activities of tsunami warning subsystem in the framework of RME too.

At present three seismic stations carry out operational work of the tsunami warning subsystem, and 50 coastal hydrometeorological stations make visual observations of the ocean surface. There are no telemetric and mareograph installations for operational measurements of ocean level. Those destroyed on Kuriles in 1994, have not yet been reconstructed as well as 3 seismic stations.

For the exchange of data between Russian regional tsunami warning centers and foreign centers, only the WMO Global Telecommunication system channels are being utilized.

Taking into account the economic crisis in Russia, realization

of the project to automate the NTWS has stopped almost fully, because of the lack of funds needed for the reconstruction of the destroyed installations of the system.

In this connection, Roshydromet expresses its thanks to IOC/UNESCO and to the Pacific Branch of NOAA for offering financial support - US$ 30,000 in 1997, and for their readiness to provide 3 sea level measuring systems on the Russian Kuriles with the equipment for data dissemination via satellites. The plan to establish and put these stations into operation was developed and is being realized by Roshydromet.

It is expected that training will be provided for 2 Russian specialists in ITIC within the framework of ITSU visiting program. It is expected to use geostationary meteorological satellite GMS-5 by JMA consent.

According to the ITSU-XV.2 recommendation, the International Workshop on Tsunami Mitigation and Risk Assessment was carried out by ITSU and IUGG in 21-24 August 1996 in Retropavlovsk-Kamchatskyi. The sponsors of this workshop were ITSU-IOC and IUGG jointly with the Russian Foundation for Basic Research (RFBR), Kamchatka Regional Administration, Kamchatka Center for Monitoring of Seismic and Volcanic Activities, Computing Center SD RAS, Novosibirsk, Institute of Computational Technologies, SD RAS, Novosibirsk.

The workshop participants were acquainted with the activities of Kamchatka regional tsunami warning center of Roshydromet and seismic station "Petropavlovsk". Proceedings of the Workshop are being finalized.

Modernization of TWS

In spite of the financial difficulties, in 1995-1997 Roshydromet with the support of Ministry of Science and Technologies has continued the improvement of information technologies in TWS. In the Retropavlovsk-Kamchatskyi tsunami center, a hardware - software unit was developed and put partly into operation. This improvement ensures: the calculation of the travel time of tsunami wave from the place of origin to various coastal zones; information support for situation analysis and for taking decisions relevant to a tsunami threat; message (telegrams) development according to operative regulation of regional tsunami service and automated output of these messages into communication channels according to outlines of transfer and distribution of information.

Another software unit was developed and tested in the tsunami center for the improvement of operational tsunami prediction on the base of the Geographic Information System, MAPINFO.

Seismic Events and Tsunamis

Seismic subsystems of Russian TWS recorded 50 strong earthquakes of magnitude more than 6 during 1995-1997 in the immediate vicinity of the Russian shores of the Pacific Ocean. One tsunami event was recorded in the area of South Kuriles 04.12.95-; The wave height was 109 sm on Shikotan island.

Proposals to ITSU-XVI Recommendations

Due to the countries-participants needs for reconstruction of PTWS seismic and tidal stations destroyed by natural disasters, it is necessary to foresee financial support in the program of activities and priorities of the International Co-ordination Group in 1998-1999.

Singapore

Tsunami Activity

Singapore is a small island state in South East Asia surrounded by the neighboring Indonesian archipelagos. Historically, there is no record of Singapore been affected by tsunami and other earthquake related disasters, except for the tremors experienced as a result of the far-field effects from distant earthquakes in the region.

Tsunami warnings/watch and information messages from PTWC are received through the GTS on WMO header WEPA40 PHEB.

Equipment

In September 1996, the Meteorological Service Singapore (MSS) established a network of digital seismic stations for the monitoring of regional seismicity and to collect scientific data for the study of the extent and intensity of tremors experienced in various parts of Singapore.

The seismic network consists of 5 classical high gain three-component seismic stations, one of them being VBB Global Seismographic Station and 2 sites with bore-hole arrays of strong motion accelerometers. Using data acquisition, storage and telemetry equipment, seismic measurements are digitally recorded and stored at various remote seismic stations and then transmitted to MSS for further processing and dissemination.

The network of tide gauge stations near the coast of Singapore Island is maintained by the Port of Singapore Authority.

USA

Introduction

Significant developments within the US Tsunami Warning System that have occurred during the intersessional period since the ICG/ITSU-XV include: improvements in automatic processing of seismic information at both the WC/ATWC and the PTWC, a change in the WC/ATWC's procedures, in its regional area of responsibility only, to include the issuance of

bulletins related to potentially tsunamigenic events anywhere in the Pacific Basin (this does not impact, in any way, the services provided by the PTWC to the international community), expansion of the Pacific Satellite Sea -Level Network, and the use of Internet by the PTWC to collect Pacific wide seismic data. The Twelfth Edition of the Communications Plan for the Tsunami Warning System was published in July 1996 and distributed.

The US developed and is now operating a communications system known as the Emergency Managers Weather Information System (EMWIN). EMWIN uses the US geostationary satellites GOES-8 and GOES-9 to transmit all forecasts and warnings (including tsunami watch/warnings and information bulletins issued by the PTWC and WC/ATWC) issued by the NWS.

The NWS Pacific Region is working with PEACESAT on a variety of activities related to the TWS. The first of these is making data on EMWIN also available on PEACESAT. This will greatly expand the footprint in which the data are available and make it available immediately to all locations with a PEACESAT receiver. The second is a co-operative effort that we are trying to develop with IRIS to use a dedicated data channel on PEACESAT to bring back Western Pacific seismic data in real-time.

The NOS continues to maintain a network of the Next Generation Water Level Measurement Systems (NGWLMS) at tide gauge sites in the US National Water Level Observation Network and at selected international locations. Data from these units are accessible to the WC/ATWC and the PTWC to support the TWS. A significant number of these gauges have been programmed to report in a specialized format for the TWS. Because of funding problems in the NOS there is the potential for a reduction in the number of international tidal stations which the NOS will maintain.

In 1996, the US Congress provided $US 2.3 million to NOAA to begin a five year program in support of tsunami mitigation activities in Alaska, Hawaii, Washington, Oregon, and California, to improve communications and seismic data in these states, to model tsunami inundation, and to begin the installation of a network of satellite reporting bottom pressure sensors for the detection of tsunamis in the open ocean. A Steering Committee has been formed consisting of representatives of the 5 states, NOAA, USGS, the Federal Emergency Management Agency (FEMA), and the NSF to oversee these activities. To date, plans have been approved regarding improved communications and seismic data, standard tsunami warning signage has been adopted, an inundation modeling center has been established, and the first bottom pressure sensor will be deployed in July 1997 with a second sensor scheduled for deployment later in 1997.

There a number of US sites on the Internet which have data of interest to the tsunami community. What follows is far from an exhaustive listing:

US Nat'l Tsunami Hazard Reduction Program
http://www.pmel.noaa.gov/tsunami-hazard

NOAA – Research
http://www.pmel.noaa.gov/tsunami

Univ. of Washington
http://www.geophys.washington.edu/tsunami/welcome.html

US Army Corps of Engineers
http://bigfoot.cerc.wes.army.mil/tsu00000.html

USGS
http://walrus.wr.uegs.gov/docs/projects/cascadia/tsunami/tsunami.html

University of Southern California
http://cwis.usc.edu/dept/tsunamis/

Wstrn States Seis Pol Coun
http://vishnu.glg.nau/edu/wsspc/tsunami/TsunamiHMC.html

Science of Tsunami Hazards Journal
http://www.ccalmr.ogi.edu/STH

ITIC Home Page
http://www.shoa.cl/oceano/itic/frontpage.html

US Nat'l Geophysical Data Center
http://www.ngdc.noaa.gov/seg/hazard/tsudb.html

Pacific Tsunami Warning Center (PTWC)

During the intersessional period through May 1997, 7 Regional Watch/Warnings were issued by the PTWC. On 30 July 1995 at 0511Z a 7.8Ms, event occurred near 23.4S 70.4W along the coast of Northern Chile. Up to 1.3m waves were detected in the source area, and smaller waves were recorded throughout the Pacific, including 50cm in Hilo, HI. Some damage was reported in the Marquesas. The watch/warning was canceled after just over an hour. On 16 August 1995 at 1027Z a 7.8Ms event occurred near 5.6S 153.9E in the Solomon Islands. A regional watch/warning was issued and Hawaii was put into a watch after one hour. The watch/warning was canceled after one and a half hours when no waves appeared at the Kapingamaringi gauge. A record was received later from Rabaul showing a 50cm wave near the source area.

On 3 December 1995, 18: 0 1 Z an 8.0 Ms event occurred near 44.6N 149.4E in the Southern Kuril Islands. A regional watch/warning was issued and canceled, just before Hawaii would have gone into a warning, 2 hours later on the basis of information received from JMA and YSTS. On 17 February 1996 at 06:00Z an 8.0 Ms event occurred at 0.1S 137.0E in the Irian Jaya region of Indonesia. A regional watch/warning was issued and canceled an hour later on the basis of wave heights recorded

near the source area. On 10 June 1996 at 04:03UTC, a 7.7 Ms event located at 51.6N 177.2W, approximately 80 km SW of Adak. tsunamis were recorded throughout much of the Pacific; the greatest, outside the source region, was recorded at Kahului, HI: 55 cm. A regional watch/warning was issued and canceled an hour later. This event was followed by an aftershock on 10 June at 15:26 near 51.5N 177.OW with an magnitude of 7.2 Ms. On 21 April 1997 at 12: 02UTC, a 7.7 Ms event occurred near 12.2S 166.3E in the vicinity of the Santa Cruz Islands. Small wave heights, 100 cm or less, were recorded on a few regional gauges. A regional watch/warning was issued and canceled after less than 2 hours.

Also during the period, 43 Tsunami Information Bulletins were issued. The associated earthquakes occurred primarily at active plate margins in the western Pacific, Mexico, Central and South America. Also, a 7.0 Ms earthquake, followed by a 6.5 Ms aftershock, occurred on the East Pacific Rise.

TREMORS, which was developed by the Laboratory d'Geophysique of France, has been implemented on the real-time IRIS data stream coming from the GEOSCOPE/IRIS seismic station Kipapa (KIP). The System automatically provides the PTWC with a rough single station earthquake location, a seismic moment, a mantle wave magnitude, Mm, and a moment magnitude, Mw. The significance of the implementation using the IRIS data stream is that the distribution of TREMORS to other broad band stations is not restricted to stations using the GEOSCOPE format. In the future it is hoped that the parametric data generated by various TREMORS operating in the Pacific can automatically be distributed to regional tsunami warning centers in the Pacific basin giving them a better measure of the potential tsunamigenic earthquake's size..

A small seismic project also continues to progress at the PTWC. A prototype low cost single component seismic station that can detect P-waves from both local and teleseismic sources and transmit these detection's via satellite immediately back to the PTWC has been operating for several months at the PTWC. Some additional work needs to be done to improve its detection capability but once this is complete, an effort to build and deploy about a dozen of these systems at existing water level gauge stations in the southwest Pacific will begin. When complete this network would cover an area about the size of the conterminous United States and be capable of providing epicenters of earthquakes in the southwest Pacific much faster than is currently possible with the data provided to the PTWC by the National Earthquake Information Center. This network together with the networks of the WC/ATWC and the NEIC would provide a high degree of redundancy for assuring the rapid location of earthquakes throughout the Pacific basin.

In the area of water level measurement improvements significant developments have occurred at the PTWC. One of these is the initiation of the receipt of water level data from 5 stations distributed along the Pacific coast of Japan from eastern Hokkaido to the western Ryukyu Islands via the GTS of the World Meteorological Organization. These data are transmitted hourly from the Japanese Meteorological Agency (JMA) to the PTWC. Efforts are underway at the writing of this report to provide the JMA with water level data from the central and eastern Pacific in addition to data they currently receive from - Alaska and the southwest Pacific. This continuous flow of data between the two agencies provides each with a better means to understand the nature of Pacific tsunamis as they are spreading across the Pacific and to aid each in making decisions regarding appropriate actions to be taken with regard to these tsunamis.

The Pacific Tsunami Warning Center is continuing to upgrade its communication software. Event messages, such as watches and warnings, are now issued automatically for all communication circuits by the Sun workstations, which make up the primary computer system for all PTWC operations. New data management methods were established to support the publication of the "Communications Plan for the Tsunami Warning System" and the Twelfth edition was issued in July 1996. Procedures have been established to issue page changes to this edition each January and July. These page changes will reflect any new information received in the first 6 months. Since the PTWC has Internet access, users of the Communications Plan can use that medium to inform the PTWC of any changes to the plan.

West Coast/Alaska Tsunami Warning Center (WC/ATWC)

During the intersessional period two warnings were issued by the WC/ATWC. The first occurred on June 10, 1996 Lat 51.6N Long 177.2W Magnitude 7.7, 50 miles SW of Adak, AK. Tsunamis -for this event (heights are peak to trough in CM) were Adak AK-102, Shemya Ak-15, Unalaska AK-12, Sand Point Ak-10, Kodiak AK-12, Kawaihae HI-15, Kahului HI-55, Nawiliwili HI-33, Hilo HI-38, Honolulu HI-10, Port Allen HI-20 Johnston Is.-3, Port Angeles WA-10, Crescent City CA-30. The second event also occurred on 10 June Lat 51.5N Lon 177.OW Mag 7.2 30 miles SW of Adak. Tsunamis for this event were masked in the background of the tsunamis from the first event.

The following Technical Paper's were submitted for publication by the Alaska Tsunami Warning Center's staff:

Whitmore, P.M. and Sokolowski, T.J., 1996. "Predicting Tsunami Amplitudes along the North American Coast from tsunamis Generated in the Northwest Pacific Ocean during Tsunami Warnings" Science of Tsunami Hazards, Vol 14, No.3, pp 147-166

Whitmore, P.M., Tsuboi, S., and Sokolowski, T.J., 1997 "Application of broad band moment magnitude (Mwp) to

teleseismic and deep focus earthquakes" Presented at the Seismological Society of Japan, March 1997, (Seiji Tsuboi, Department of Geosciences, National Defence Academy, Yokosuka, Japan)

Research Activities

The US continues to support tsunami research through the federal agencies of NOAA, DARPA, and NSF. The following 3 activities represent major highlights of the past two years: 1) Inundation Model Comparison - In September 1995, NSF sponsored a workshop to compare 5 tsunami inundation models. Each model was tested for an analytical case and the 1993 Sea of Japan tsunami on Okushiri Island. For each case the models were initialized the same and inundation results were compared. The two models that performed the best were the Shuto model used for the TIME project and the Titov/Synolakis model developed at the University of Southern California. 2) Data collection for June 1996 Andreanov Tsunami - In October 1996, DARPA funded a project to assemble tsunami data from existing tide gates, coastal pressure gages, and deep ocean gages to thoroughly document and archive a Pacific wide tsunami to use in model verification. Over 150 records were examined from throughout the Pacific and from this set tsunamis were recorded on 47 instruments. These data will be archived and made available at the US Nat'l Tsunami Hazard Reduction Program website listed above. 3) Operational Prototype of Deep Ocean Tsunami Detector Completed - In July, 1997, NOAA deployed its first operational prototype deep ocean tsunami detection system off Kodiak, Alaska. Tsunami data are available in near real-time from the buoy to PTWC through the NOAA GOES satellite. This culminates over 15 years of sensor testing and systems development by NOAA.

International Tsunami Information Center (ITIC)

The United States, recognizing the important role of the ITIC in coordinating international aspects of the Pacific Tsunami Warning System and ITSU, has continued to support of the Center as a stable level. Dr. Charles S. McCreery was appointed the ITIC Director shortly after ITSU-XV. Fortunately, he was available to attend ITSU-XV in Papeete. Mr. Salvador Ferraras, seconded by Mexico as the Associate Director continued in that capacity until April of 1996. The intersessional period was a very active one for the ITIC and the details will be contained in the Director's Report to ITSU-XVI.

National Geophysical Data Center (NGDC) and World Data Center A (WDC-A) for Solid Earth Geophysics

A new publication of the NGDC became available in 1996. "Tsunamis Affecting Alaska, 1737-1996" is the third in a series of informative publications about tsunamis written by James F. Lander. The catalogue describes all known tsunamis that have affected Alaska in historic time, expanding the information first provided in United States Tsunamis, 1690-1988. Detailed description information is included to better characterize the tsunami hazard. The text is illustrated with pictures, tables, marigram records, and other figures. A separate section is included for the Prince William Sound event of 1964. 195 pages, 55 illustrations, 15 tables, and 42 marigrams. It is available in soft cover format.

Also, a new slide set, "The Shikotan, Kuril Islands Earthquake and Tsunami, 4 October 1994" became available. This new slide set depicts the after effects of this event, and includes several views of the tsunami damage and evidences of wave height. Slides and descriptive material were provided to NGDC by Viacheslav K. Gusiakov, Computer Centre, Novosibirsk 630090, Russia.

An international symposium was held 29 March - 1 April 1996, at Hilo, Hawaii by G. Curtis and J.F. Lander (NGDC) to commemorate the anniversaries of the great Sanriku, Japan's tsunami of 1896 and the 1946 Aleutian Tsunami. The 1946 event was the immediate cause of the initiation of the Tsunami Warning System, and the revival of the international tsunami research effort. Eleven Japanese participants and 20 participants from the US. The workshop received high visibility with a memorial service at the court house.

ICG/ITSU-XVI Agrees to Changes in Earthquake Reporting Procedures and Message Generation Criteria

At it's Sixteenth Session in Lima, Peru the ICG/ITSU recommended that seismological stations providing data to the PTWC during potentially tsunamigenic earthquakes include information that may be useful for determining the depth of the earthquakes. This information could be an actual focal depth determined by stations close to the epicenter or the arrival times of both the P-wave and the pP-wave.

In the discussion prior to the Group's recommendation it was pointed out that the current procedures use only the earthquake magnitude and location as criteria for issuing warnings and watches. This can lead to unnecessary warnings being issued for events that are too far below the earth's surface to generate tsunamis or missed warnings for "tsunami earthquakes" that yield unusually large tsunamis for their magnitudes. It was suggested that the number of criteria used be increased to four: epicenter location, focal depth, source size, and source duration. The epicenter location is rather obvious. The earthquake should be located within or near the sea. The "source size" has for decades been based on the surface wave magnitude, Ms, which is proportional to the amplitude of the 20-second Rayleigh wave, corrected for distance from the recording station to the epicenter. Source size is now beginning to be routinely determined from the seismic moment that considers a much broader spectra of seismic waves. The source duration is a potential means of identifying "tsunami earthquakes." A longer duration is indicative of a slower, complex rupture process. Such a slower fault rupture will tend to be richer in long period seismic waves. Thus, a spectral analysis indicating that more energy is present at longer periods could mean a relatively large tsunami has been generated. Such spectral analyses are possible for teletsunamis within the warning issuance time frame. Better focal depths may be determined if seismological stations providing data to the PTWC comply with the ICG/ITSU recommendation.

In addition, at the Lima meeting, the ICG/ITSU accepted the recommendation of the PTWC Director to eliminate the special magnitude criterion that had been in place for the Aleutian Islands for a long time, probably since the establishment of the Tsunami Warning System in the Pacific. For all areas of the Pacific, except for the Aleutians, a warning is not issued until a potentially tsunamigenic earthquake's magnitude exceeds 7.5. For the Aleutians this criterion was lowered to 7.0. The reason for this was that no matter how hard the seismologists tried they simply could not raise the magnitude of the 1 April 1946 Unimak Island earthquake above about 7.4. This earthquake generated an unusually large tsunami that struck Hawaii and caused the worst natural disaster ever to strike that State, particularly in terms of loss of life. It is now believed that this event was a "tsunami earthquake." The PTWC is confidant that techniques now in place at the Center will allow it to recognize "tsunami earthquakes" in sufficient time to issue adequate warnings. The ICG/ITSU will closely monitor the effect of this change. This modification will be incorporated into the next issue of the Communications Plan.

Pacific Tsunami Warning Center

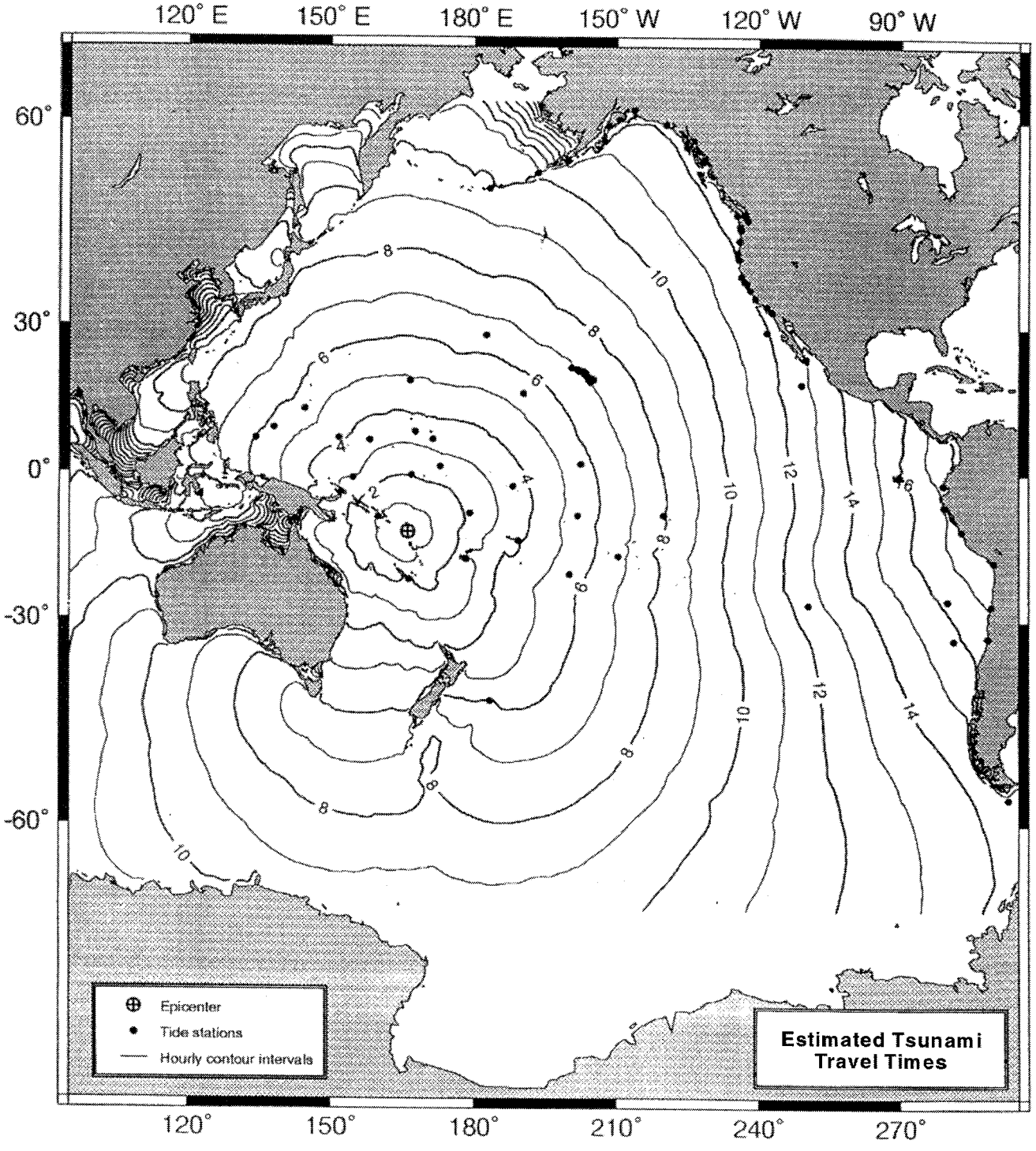
Charles "Chip" McCreery became the Geophysicist-in-Charge at the PTWC on October 1, 1997. From 1995 until his transfer to the PTWC Chip had been the Director of the ITIC. Dr. McCreery was a member of the PTWC staff, beginning in 1993, prior to assuming the Directorship at the ITIC. For more than twenty years, before entering U.S. govement service, Chip had been a student and then an employee of the University of Hawaii at Manoa. Dr. McCreery did both his undergraduate and graduate work at the University of Hawaii where he received his doctorate. He worked with Dr. Dan Walker on studies of seismic waves travelling near the ocean-sea floor interface and in the SOFAR channel. Together they studied relationships between T-phases and tsunamis.

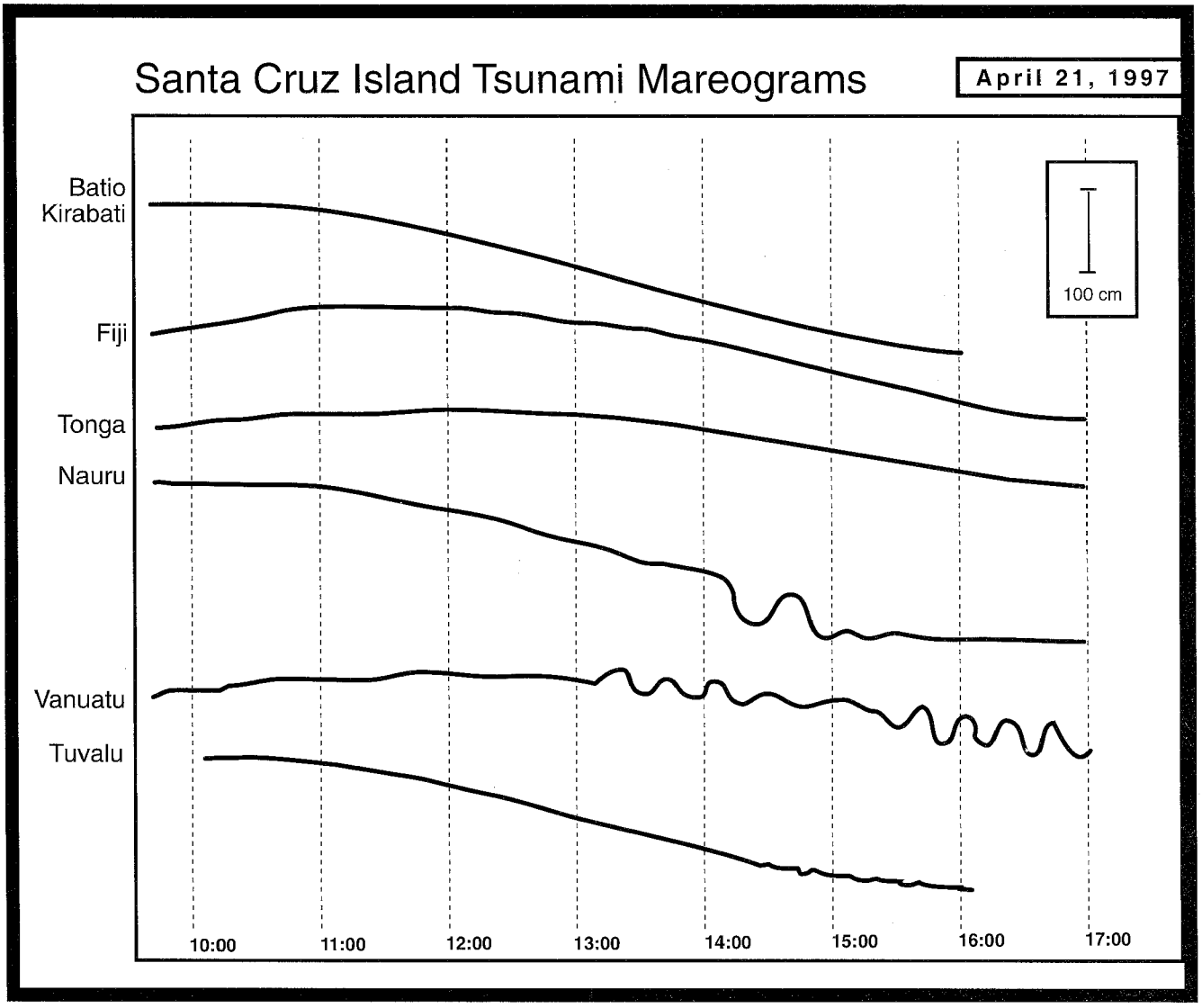
International Tsunami Information Center

On October 1, 1997 Michael Blackford became the Acting Director of the ITIC, pending approval of his appointment as Director by the IOC Executive Secretary. He replaced Charles "Chip" McCreery who assumed the Geophysicist-in-Charge position at the PTWC. Mr. Blackford was the Geophysicist-in-Charge at the PTWC from 1991 until his transfer to the ITIC. Mr. Blackford has been a career geophysicist with the United States government specializing in basic and applied seismology. He was a member of the staff at the West Coast and Alaska Tsunami Warning Center from 1978 to 1984. In addition to his time with the tsunami program, Mr. Blackford has also worked at the Geological Survey and the Nuclear Regulatory Commission within the U.S. government. He moved to the ITIC so that he could focus more of his time on the international aspects of tsunami warning and tsunami risk mitigation.

Santa Cruz Islands Earthquake and Tsunami, Mw=7.8

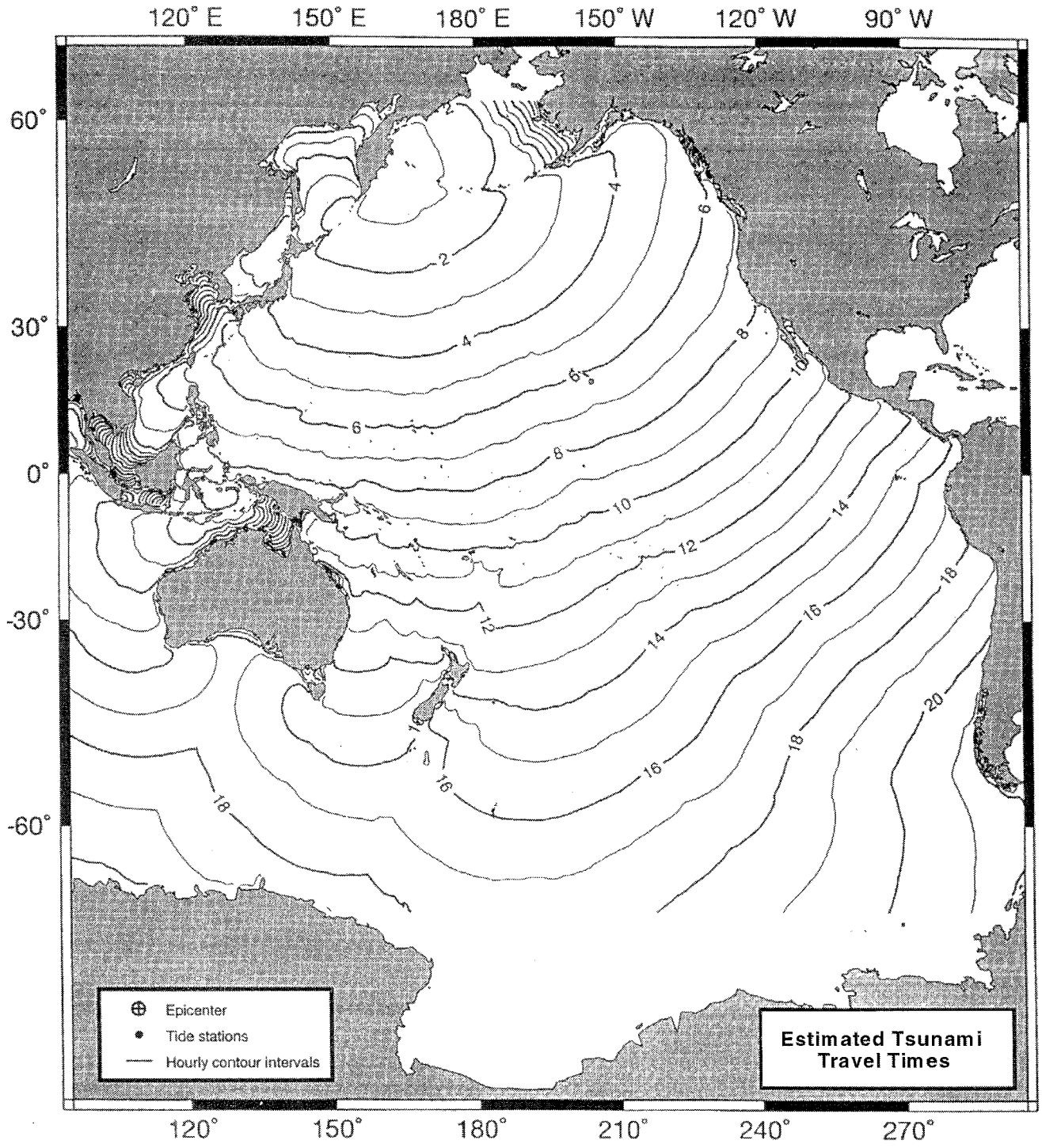
21 Apr 1997 1202 GMT 12.47°S 166.21°E

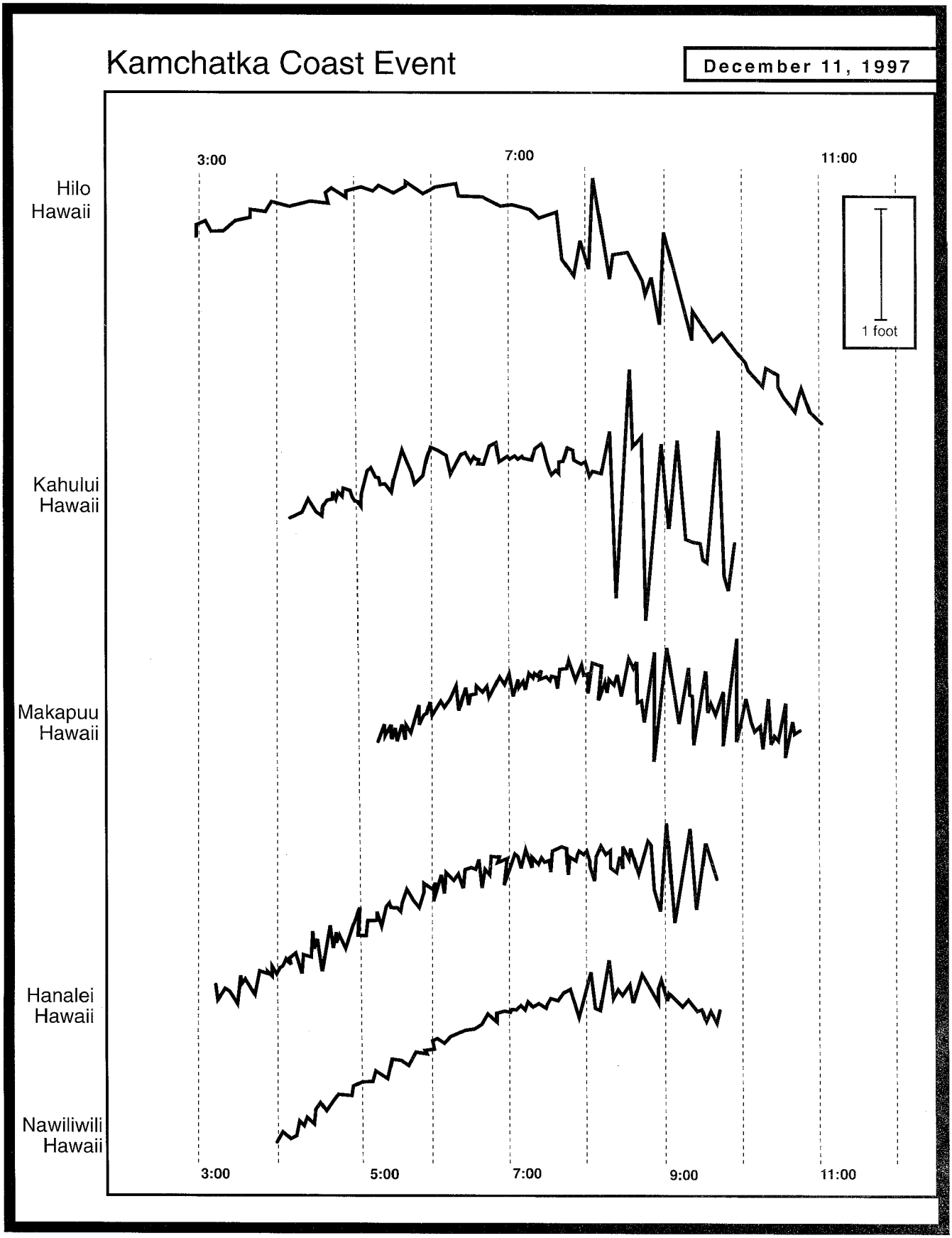



Santa Cruz Island Tsunami Mareograms
April 21, 1997
Batio Kirabati
Fiji
Tonga
Nauru
Vanuatu
Tuvalu
100 cm
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00

Kamchatka Earthquake and Tsunami, Mw=7.9

5 Dec 1997 1126 GMT 54.7°N 163.6°E




Kamchatka Coast Event
December 11, 1997
3:00
7:00
11:00
Hilo
Hawaii
1 foot
Kahului
Hawaii
Makapuu
Hawaii
Hanalei
Hawaii
Nawiliwili
Hawaii
3:00
5:00
7:00
9:00
11:00

Summary of Pacific Basin Earthquakes 1997

With Surface Wave or Moment Magnitudes Greater than or Equal to 6.5

(extracted from NEIC QED and PTWC Log)

Date	Time	Lat	Lon	Dep	Ms	Mw	Location	PTWC	Issued	Tsu-nami
970111	2028	18.2	-102.8	40	6.9	7.2	Michoacan Mexico	TIB	2107	
970123	0215	-22.0	-65.7	281	-	7.1	Southern Bolivia			
970311	1922	7.7	127.6	10	6.7	6.9	Mindanao Philippines	TIB	2021	
970326	0209	51.3	179.5	30	6.5	6.7	Rat Is. Aleutian Is. AK	TIB	0238	
970405	1224	-6.5	147.4	69	-	6.5	E. New Guinea PNG			
970421	1202	-12.6	166.7	28	7.9	7.8	Santa Cruz Islands	RWW	1304	Yes
970423	1944	14.0	144.9	95	-	6.5	Mariana Is. N of Guam			
970501	1138	19.0	-107.4	12	6.8	6.9	Off Jalisco Mexico	TIB	1219	
970503	1646	-31.8	-179.4	108	-	6.9	Kermadec Islands			
970511	2216	-36.4	-97.7	10	5.8	6.5	West Chile Rise			
970521	1410	-20.4	169.3	57	6.5	6.8	Vanuatu Islands			
970522	0751	18.7	-101.6	61	6.0	6.5	Guerrero Mexico			
970525	2323	-32.1	179.8	340	-	7.1	S of Kermadec Islands			
970529	1703	-36.0	-102.5	15	6.1	6.5	Southern E. Pac. Rise			
970610	2154	-35.8	-108.1	15	6.1	6.5	Southern E. Pac. Rise			
970617	2104	51.3	-179.3	15	6.6	6.4	Andreanof Islands	TIB	2135	
970706	0954	-30.1	-71.9	19	6.5	6.8	Nr Coquimbo Chile	TIB	1127	
970719	1422	16.3	-98.2	10	6.3	6.8	Guerrero Mexico			
970808	2227	-15.5	-179.1	15	6.6	6.6	Fiji Islands Region	TIB	2305	
970829	0654	-15.2	-175.6	28	6.4	6.5	Tonga Islands			
970829	0814	-3.6	144.4	23	6.4	6.6	N New Guinea Coast			
970902	1213	3.8	-75.7	199	-	6.8	Colombia			
970904	0424	-26.6	178.3	625	-	6.8	South of Fiji Islands			
970920	1612	-28.7	-177.6	30	7.0	7.2	Kermadec Is. Region	TIB	1706	
970930	0627	32.0	141.9	10	6.5	6.1	S of Honshu, Japan	TIB	0701	
971006	1230	9.8	125.8	106	-	6.5	Mindanao Philippines			
971014	0953	-22.1	-176.8	167	-	7.7	South of Fiji Islands	TIB	1045	
971015	0103	-30.9	-71.2	58	6.8	7.1	Nr Cent Chile Coast	TIB	0158	
971028	0615	-4.4	-76.7	112	-	7.2	Northern Peru			
971115	1859	-15.1	167.4	123	-	7.0	Vanuatu Islands	TIB	1945	
971125	1215	1.2	122.5	24	6.8	7.1	N. Sulawesi, Indo.	TIB	1308	
971205	1127	54.8	162.0	33	7.6	7.9	Nr Kamchatka Coast	RWW	1209	Yes
971217	0439	51.2	178.9	20	6.5	6.7	Rat Is. Aleutians, Ak	TIB	0512	
971222	0206	-5.5	147.9	179	-	7.1	E New Guinea Coast			

Obituary

Professor Mohammed El-Sabh, 1939-1999

Professor Mohammed El-Sabh, 59, died unexpectedly on 8 February 1999, following a heart attack. The University of Quebec at Rimouski (UQAR) and all of Quebec have lost a major personality who made Rimouski known around the world for its marine sciences.

Born in Egypt, Mohammed El-Sabh obtained his Ph.D. from McGill University in Montreal. He arrived at UQAR in 1972 to form part of the first team of researchers given the mission of developing oceanography at Rimouski. Through his teaching and research as well his numerous publications and involvements, he contributed in a major way to the growing reputation of UQAR both nationally and internationally.

At UQAR, he supervised more than 20 M.Sc. and Ph.D. students in oceanography. At their request, he often evaluated work being done at other universities as well.

From his research, he produced several major scientific publications, including Natural and Man-Made Hazards (Netherlands, 1986), Oceanography of the St. Lawrence Estuary (Germany, 1990) and Integrated Management and Sustainable Development in Coastal Zones (United States, 1998).

This Rimouski researcher participated greatly in a wide range of colloquia and special meetings around the world, always with the objective of better understanding the coastal environment and contributing to the prevention of natural disasters and to the limitation of their effects. In the course of this work, he developed an impressive worldwide network of professional contacts in marine sciences.

Mohammed El-Sabh was awarded numerous prizes, notably: the International Tsunami Society Merit Medal (for the organisation of the International Symposium on Hazards and Disasters in Rimouski, 1986), the Applied Oceanography prize of the Canadian Society of Meteorology and Oceanography, the Michel-Jurdant prize (Environmental Sciences, ACFAS, 1991), the Alcide C. Horth Distinction (for his contribution to research), the Prix de reconnaissance (UQAR, 1997) and the Science Prize of the International Society for Natural Hazards (1998).

Within the university, he was twice Director of the Department of Oceanography. Last autumn, he took on the administrative and scientific leadership of the PRICAT project, aimed at developing links in the field of Marine Resources between Canada and Tunisia. He was also a member of the Board of Directors of the Fondation de l'UQAR.

A major personality has been lost to us. Many people will warmly remember this friendly, enthusiastic man who found his niche in Quebec society. He was the companion of Mme. Pauline Cote, Professor of Education at UQAR and the father of two children, Youssef and Nadia.

From comments by Philip Hill, Acting Director, Department of Oceanography, University of Quebec at Rimouski

Meeting Announcements

Tsunami Symposium

Sponsor: The Tsunami Society

Dates: May 25-27, 1999
Place: University of Hawaii East-West Conference Center
Honolulu, Hawaii

Contact: Dr. Charles Mader, Program Chairman
1049 Kamehame Drive, Honolulu, HI 96825-2860

Tsunami Workshop

Sponsor: IUGG/Tsunami Commission

Dates: September 30 to October 2, 1999
Place: Seoul, Korea

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